# Case study: Integrated Infrastructure Planning

Deliverable 4.2

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# Abstract

This report falls within Task 2 of Work Package 4 of the 4I-TRACTION project, where we investigate specific core policy instruments that can induce a transformative impact towards a climate neutral EU. Four core policy instruments are investigated in individual case studies. This report contains a case study for the policy instrument *Integrated Infrastructure Planning,* with a focus on transnational energy infrastructure. Timely roll out of the necessary energy infrastructure is a key factor in the transition to a climate neutral energy system and reaching the climate goals. This requires proper and integrated infrastructure planning processes, also on European level.

The report describes current EU policies regarding transnational energy infrastructure and discusses which gaps exist in the light of reaching a climate neutral European energy system. Furthermore, it contains different options for the policy instrument *Integrated Infrastructure Planning.* These are designed to cover the existing policy gaps and incorporate a pan-European view on transnational energy infrastructure planning. At last, an assessment of the impact of the different policy options is given.

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# Abbreviations

| | |
|---|---|
| ACER | Agency for the Cooperation of Energy Regulators |
| ENNOH | European Network of Network Operators for Hydrogen |
| ENTSO | European Network of Transmission System Operators |
| ISO | Interconnection Systems Operator |
| NRA | National Regulatory Agency |
| PCI | Projects of Common Interest |
| PMI | Projects of Mutual Interest |
| TEN-E | Trans-European Network for Energy |
| TSO | Transmission Systems Operator |
| TYNDP | Ten-Year Net Development Plans |

# Executive summary

**The energy system has to change rapidly and considerable investments in energy infrastructure are necessary to facilitate these changes and meet the EU's climate policy objectives.** Fossil fuels have to be phased out and replaced by renewable energy sources. A climate neutral energy system, however, requires a fundamentally different energy infrastructure than the current fossil-dominated energy system. Given the long lead times, timely roll-out of this energy infrastructure is crucial. This applies to both infrastructure investments within Member States as investments in transnational energy infrastructure between Member States. In this case study we focus on the latter and investigate potential improvements of the policies regarding transnational energy infrastructure within the EU. We primarily consider electricity and hydrogen infrastructure since these energy carriers are expected to play a key role in a climate neutral energy system.

**Realisation of transnational energy infrastructure requires significant investments, but also leads to benefits for the energy system.** The main benefits of transnational energy infrastructure investments are higher utilisation of renewable energy production. This leads to less curtailment and less gas-based generation, reduction of greenhouse gas emissions and increased security of supply within the EU. If investment planning is done efficiently, the benefits of investments in transnational energy infrastructure outweigh the costs and consequentially lead to lower overall energy costs and total energy system costs. Underinvestment or overinvestments in transnational energy infrastructure, on the other hand, will lead to higher costs for the energy system and may delay the transition towards a climate neutral energy system in the EU.

This emphasises the necessity of proper planning of this transnational energy infrastructure. A pan-European and integrated view on the planning and realisation of transnational energy infrastructure is necessary to reach an optimal level of interconnection in the EU and a resilient cost-efficient climate neutral energy system.

**With current policies and governance, the planning of transnational energy infrastructure mainly takes place at Member State level.** Some processes take place at EU level to incorporate a pan-European view on the roll-out of interconnections. Current policies include the establishment of Ten-Year Network Development Plans (TYNDP) by the European Network of Transmission System Operators (ENTSOs) and assignment of the Projects of Common Interest (PCIs) by the European Commission. However, the TYNDPs are non-binding and the PCI status can only give a nudge towards incorporation of a pan-European perspective. All formal competences for the planning and realisation of transnational energy infrastructure are situated at Member State level with national or regional Transmission System Operators, national or local governments and national regulators. This also means that investments in interconnections are made separately by a large number of TSOs, rendering the decision making process rather fragmented.

**Different options exist to improve current policies, to reach an optimal decision on investments in transnational energy infrastructure.** To incorporate a pan-European view on transnational energy infrastructure planning and investment decisions, policies guaranteeing an integrated and coordinated infrastructure planning at EU level are likely to be necessary. Different policy options were identified that could achieve this, largely distinguished by different governance approaches and by the levels of integration of the infrastructure planning. The three policy options that were investigated are:

- **Fragmented governance (policy option 1).** This policy option is closest to the current situation, with some improvements. Policy remains based on voluntary collaboration between Member States. The PCI procedures and TYNDPs of the ENTSOs would be continued but become more transparent and objective.
- **Pan-European governance (policy option 2).** This is the most transformative policy option that was investigated. With this policy option, all competences for transnational energy infrastructure are transferred to EU level. The governance is fully European. One European Interconnection Systems Operator (ISO) is formed as responsible entity for the realisation and operation of transnational energy infrastructure for all energy carriers. EU entity ACER receives formal competences as regulator of the ISO.
- **Middle-of-the-road (policy option 3).** This option is located between the first two. With this option, the ENTSOs are strengthened and they receive formal competences to impose capacity and timeline requirements for transnational energy infrastructure to existing TSOs, with regulation and control by ACER. The realisation and operation of the transnational energy infrastructure remains the responsibility of individual TSOs.

The impact of these three policy options was assessed against various criteria, see Table 1 for a summary. The following conclusions can be drawn from this assessment.

**A pan-European view on transnational energy infrastructure planning is necessary for the realisation of an efficient climate neutral European energy system**. This pan-European view should be guaranteed within policies and governance, in contrast to the non-binding processes like the TYNPDs of the ENTSOs and the PCI procedures in current legislation. Indeed, to reach the goal of an efficient climate neutral European energy system, a more comprehensive and transformative approach is considered more effective than the current fragmentated decision-making process, which often leads to incremental changes only. The planning of transnational energy infrastructure should be designed from a desired end state of a climate neutral European energy system (back-casting).

Our results show that this comprehensive approach can, in principle, be implemented most effectively by transferring all competences regarding planning of transnational energy infrastructure to EU level. This implies forming one European Interconnection Systems Operator (ISO) as responsible entity for planning, realisation and operation of transnational energy infrastructure for all energy carriers (option 2).

**A EU centralised approach allows for an integral view on the development of not only energy infrastructure, but for the energy system as a whole**. Transnational energy infrastructure is just a small part of the total energy system. However, the EU centralised approach could be expanded to other aspects of the energy system, including the development of renewable energy sources, energy storage and energy import, to incorporate a true integral EU view on the development of the entire energy system. This would lead to additional efficiency benefits.

**However, realisation of a EU centralised approach is challenging and has drawbacks.** Even though transferring all competences for transnational energy infrastructure to the EU level is expected to be the most effective approach for achieving the 2050 objectives, realising this centralised approach is challenging, and severe barriers would need to be overcome. Transferring competences from Member State level to EU level may be opposed by Member States since they will have to give up part of their sovereignty. Furthermore, the increased physical and cultural distance between decision-makers and local communities increases the risk of poor interaction with the local stakeholders, lack of public support, suboptimal spatial planning, delays in permitting processes.

**A more middle-of-the-road approach with fewer barriers would be to impose binding requirements to TSOs for the development of transnational energy infrastructure.** This is our policy option 3. Here, it would still be possible to implement a pan-European view on the infrastructure and energy system, while keeping competences for the realisation of transnational energy infrastructure at Member State level. However, with this policy option decision-making remains fragmented, which makes it more challenging to effectively incorporate a pan-European view on the development of transnational energy infrastructure and the European energy system as a whole.

**Rigorous changes in legislation are expected to be necessary to adequately face the enormous task of reaching climate neutrality in the EU in less than three decades.** Even though transferring all competences for transnational energy infrastructure to EU level may seem politically unattainable right now, rigorous and transformative changes like this may be necessary in the transition toward climate neutrality. The policy option with a single pan-European entity that is responsible for all transnational energy infrastructure investments fits well within a policy framework in which all resources within the EU are used to make sure the climate targets are met.

*Table 1 Impact assessment policy options*

| Assessment criteria | Policy option 1: Fragmented governance | Policy option 2: Pan-European governance | Policy option 3: Middle-of-the-road |
|---|---|---|---|
| Ensuring optimal selection of interconnections, from pan-European perspective | No guarantee that pan-European perspective will prevail above national interests | ISO with complete mandate will guarantee realisation of optimal selection of interconnections | Binding requirements by ENTSOs for TSOs will guarantee realisation of optimal selection of interconnections |
| Speed of realisation (once policy option is implemented) | Fragmented planning by large number of TSOs. But faster realisation because of better knowledge local situation. | Integrated planning for whole EU by ISO. But more complex realisation because of limited knowledge local situation. | Two steps in planning process, so more complex. But faster realisation because of better knowledge local situation. |
| Transformative impact | Fragmented planning process and not reasoned from desired end state for EU | Centralised planning and realisation by ISO, which can reason from desired end state for EU | Desired end state for EU translates into obligations for Member States, but risk of fragmented planning and realisation |
| Barriers for implementation | Close to current situation, relatively easy to implement | Requires significant changes in legislation, which requires political will, implementation time and transfer of knowledge | Same barriers as policy option 2, but to lesser extent because fewer changes in legislation are necessary |
| Interaction other policy instruments | For each of the policy options, the interaction with other policy instruments may occur in different manners and on different governance levels. However, in this study we cannot draw conclusion on whether the different policy options interact better or worse with other policy instruments. | | |
| Social and distributional aspects | Realisation by regional or national TSO with less (physical and cultural) distance to the local population. So less risk of negative social and distributional effects | Risk of poor interaction with local stakeholders, poor balance of costs and benefits and risks of local opposition because of large distance of ISO to local population. Would need to be counteracted explicitly. | Realisation by regional or national TSO with less (physical and cultural) distance to the local population. Accordingly less risk of negative social and distributional effects |
| Competitiveness and employment | More interconnections lead to lower electricity prices and convergence of prices across EU, which increase competitiveness of EU.<br><br>No substantial differences for employment. Most of the employment is related to the realisation of the transnational energy infrastructure and it is expected that the realisation of the interconnections will be performed by local contractors in all three policy options | | |

# 1. Introduction

## 1.1 Background

Climate policy in the EU must switch gears from incremental improvements towards a transformative approach that fundamentally restructures the economy in line with climate neutrality. The European Green Deal expresses a transformative ambition to make Europe the first climate neutral continent. However, it is unclear if the Fit for 55 Package and the RePowerEU Initiative amending it are able to deliver the transformative impulse needed to put the EU on the path to climate neutrality. Irrespectively, the EU will have to double down on its efforts soon, designing policies for the period after 2030, and taking the 2050 target into view. In short, the EU needs to adopt transformative policies that take the continent toward climate neutrality.

The 4i-TRACTION project explores the possibilities and consequences of transformative actions on four domains, one for each of the four Is (Innovation, Investment, Infrastructure, Integration). Work Package 4 of this project aims to develop climate policy avenues that are transformative in nature, i.e., instruments that contribute to transformative change. This report falls within Task 2 of Work Package 4, where we investigate specific core policy instruments that can induce a transformative impact towards a climate neutral EU. Four core policy instruments are investigated in individual case studies, each linked to one of the four Is. In Table 2 an overview is given.

*Table 2 Core policy instruments of Work Package 4, Task 2 of the 4i-TRACTION project*

| Domain | Core instrument | Author |
|---|---|---|
| Innovation | A *Transformation fund* focusing on stimulating sustainable innovation | VUB, WUR |
| Investment | *Mandatory transition plans* for banks as a means to steer towards sustainable investments | I4CE |
| Infrastructure | *Integrated Infrastructure Planning* aiming to guarantee a European viewpoint on infrastructure planning | CE Delft |
| Integration | *Climate Neutral Public Procurement* to stimulate demand for cleaner goods and services | UEF, Ecologic |

The four core policy instruments are linked to the policy avenues that are developed in Task 1 of Work Package 4. The four policy avenues describe distinct climate policy mixes for attaining climate neutrality in the European Union. Policy avenues are a mix of policy instruments and institutions that are sequenced over time. The four policy avenues follow different design principles that are based on selected traditions of (climate) policymaking. They thus highlight the different paths that can be taken by EU policy going forward and can inform decision making. The four policy avenues are (Görlach et al., 2022):

1. The **Green Economic Liberalism** Policy Avenue is based on redirecting market forces and private initiative to drive the transition to climate neutrality.
2. In the **Green Industrial** Policy Avenue, the state actively builds a green economy to achieve climate neutrality. The policy avenue aims to foster breakthrough innovations in technologies that will be needed to reach climate neutrality and aims to scale existing solutions by accelerating their market diffusion.
3. The **Directed Transition** Policy Avenue aims to foster technological change through active government intervention and the direct phase-out of fossil technologies. This includes the heavy use of EU-level targets, carbon budgets, sectoral pathways, and strict standards.
4. The policy avenue **Sufficiency and Degrowth** aims to increase human well-being and address climate change by reducing material and energy use, including via methods that could reduce economic activity.

In this case study, a core policy instrument for the "I" infrastructure is investigated. The investigated core policy instrument for infrastructure is *Integrated Infrastructure Planning.* The focus is on energy related infrastructure, i.e., electricity infrastructure and gas infrastructure. Flexibility technologies like batteries, power-to-x and dispatchable powerplants are essential for the energy transition and closely linked to the energy infrastructure, so these are also considered. Non-energy-related infrastructure, like road or rail infrastructure is out of scope. We only consider the hardware of energy infrastructure, such as transmission lines, electricity substations and pipelines. Software for smart energy infrastructure is excluded. We focus on the requirements for the development of energy infrastructure from 2030 to 2050.

The following sections contains a further introduction of the core policy instrument for infrastructure.

## 1.2 Problem statement and introduction of core instrument

The energy system has to change rapidly to meet the climate targets in the EU. The use of fossil fuels needs to be phased out and be replaced with production and use of renewable energy sources. A climate neutral energy system requires a fundamentally different energy infrastructure than the current fossil-dominated energy system and considerable investments are necessary for this transformation. Timely roll-out of this energy infrastructure is crucial to meet the climate targets in Europe.

Currently, building and operating electricity and natural gas infrastructure in Europe is a regulated activity which is performed by appointed national grid operators. Usually, the electricity grid operators are different entities than the gas infrastructure operators. Building and operating other types of energy infrastructure like heat infrastructure, CCS infrastructure and hydrogen infrastructure is market-based. The deployment of flexibility technologies that provide services such as energy storage, demand side response, power-to-x and dispatchable power plants, which are essential for the future energy system, is also market-based but not yet developed at large scale.

In the future energy system, the interdependency of different types of energy infrastructure, the interdependency between flexibility technologies and energy infrastructure and the interdependency between countries will all increase. However, different bodies (some regulated and some commercial) are responsible for the planning and realisation of different types of energy infrastructure, energy infrastructure in different countries and flexibility technologies. This can lead to suboptimal integration which may consequentially lead to delay of the energy transition or additional societal costs. Some regulation is present for integration (like the TEN-E regulation for integration between countries), but further integration of infrastructure with the policy instrument *Integrated Infrastructure Planning* may be a solution. The core policy instrument *Integrated Infrastructure Planning* is the topic of this report.

We identify three possible types of *Integrated Infrastructure Planning*[1]:

1. ***Transnational integration of energy infrastructure.*** Individual countries cannot be seen as islands in the future European energy system. Currently, the energy infrastructure of Member States is connected by cross-border connections. TEN-E regulation and the Ten-Year Net Development Plans of the European Networks of Transmission System Operators (ENTSO-E and ENTSOG) are existing instruments that stimulate transnational integration of energy infrastructure. But further integration of the energy infrastructure between countries is desirable for the future. Transnational integration may contribute to balancing and security of supply of the energy system, especially for electricity. Furthermore, it may lead to more efficient use of the available renewable energy sources in Europe. With transnational integration, countries with an abundance of renewable energy sources may supply countries with limited availability of renewable energy sources, both systematically and during shorter low production periods.
2. ***Integration between different types of energy infrastructure.*** In the future, the interdependency between different energy carriers will increase. For example, the electricity and the hydrogen system will be closely linked by electrolysers (which produce hydrogen using electricity) and hydrogen power plants (which produce electricity from hydrogen). However, the infrastructure of these different energy carriers is currently

[1] Integrated planning of the energy system as a whole, including supply and demand, can also be considered a form of integrated planning. However, this is out of scope of the research since the focus is on infrastructure.

operated by different parties. Further integration of the planning processes of the energy infrastructure of different energy carriers will therefore be necessary.

3. ***Integration between energy infrastructure and flexibility technologies*.** Further integration of planning of energy infrastructure and flexibility technologies may be desirable, because of their interdependency and because of the importance of flexibility technologies for the stability and security of supply of the future energy system. Flexibility technologies can ensure that energy infrastructure is used more efficiently which means less investments in new energy infrastructure may be necessary. But, with poor integration of flexibility technologies and energy infrastructure, flexibility technologies may lead to additional necessity for new energy infrastructure.

In this case study, the focus is on transnational infrastructure within the EU, so on energy infrastructure between countries. Transnational integration of energy infrastructure is most important for electricity and hydrogen, so the analysis will be limited to these two energy carriers. Energy infrastructure within Member States is not considered explicitly.

The integration between different types of transnational energy infrastructure and the relation between transnational energy infrastructure and flexibility technologies is considered, but is not the main focus in the report.

The core instrument *Integrated Infrastructure Planning* is relevant for all four policy avenues, since timely and efficient roll-out is a critical boundary condition for reaching a climate neutral EU, no matter how climate neutrality is reached. Different options for *Integrated Infrastructure Planning* are investigated in the case study and these options are linked to individual policy avenues.

## 1.3 Goal of the case study

The goal of this case study is twofold. First, we seek to investigate how the core instrument *integrated infrastructure planning* may be shaped. Second, we seek to perform a qualitative and quantitative assessment of the impact of the policy instrument on reaching climate neutrality in the EU. The following subquestions are answered to reach this goal:

- What does a climate neutral European energy system look like and what transnational infrastructure is necessary for an efficient climate neutral system?
- What are the current EU policies related to energy infrastructure, including infrastructure planning? And what are gaps in the existing EU policies to reach a climate neutral European energy system?
- How can the policy instrument integrated infrastructure planning be shaped to cover these gaps?

- What is the impact of different options of the core policy instrument on the relevant assessment criteria?

## 1.4 Reading guide

This report consists of the following chapters:

- In **Chapter 2,** the approach of the research is discussed.
- **Chapter 3** describes the possible developments toward a climate neutral energy system in the EU. This answers the first subquestion.
- **Chapter 4** gives an overview of the current policy landscape and the gaps in the existing legislation. This answers the second subquestion.
- In **Chapter 5**, different policy options for the core policy instrument are described. This answers the third subquestion.
- **Chapter 6** consists of a description of the assessment framework and the impact assessment of the policy instrument. This answers the fourth subquestion.
- **Chapter 7** contains the conclusions and policy recommendations.

# 2. Research approach

The goal of this case study is twofold. First, we seek to investigate how the core instrument *integrated infrastructure planning* may be shaped. Second, we seek to perform a qualitative and quantitative assessment of the impact of the core policy instrument on reaching climate neutrality in the EU. Literature research, interviews with experts and stakeholders and energy modelling are used as main methods to investigate the core instrument in this case study. In the following sections, we elaborate how the sub questions, stated in Section 1.3, are answered.

## 2.1 Climate neutral Europe: system analysis

The first step analyses the development of a climate neutral European energy system in 2050. Based on literature research we describe the large trends that are expected to govern the transition between the current fossil-based energy system and the future one, which is climate neutral. This provides the context and basis for the following chapters of the report. The large changes in the European energy system will have considerate impacts on the requirements for energy infrastructure.

Within this larger energy transition context, we focus in particular on the energy carriers electricity and hydrogen. The main focus is on the impact of developments of the energy system on the necessary transnational energy infrastructure. The literature review substantiates our focus for these energy carriers for the remainder of this report. Based on literature research an overview is made of possible future configurations of transnational European energy infrastructure.

## 2.2 Current polices: overview and gaps

Firstly, an overview of the current EU policies related to energy infrastructure is made based on literature review and interviews. This is necessary to determine the 'policy gaps' in current legislation. The main focus is on EU policy related to transnational energy infrastructure, but also other types of policies are investigated to get an integral view of the current policy landscape. Upcoming legislation is also considered, for example from the Green Deal or the revision of the Electricity Directive.

After the overview of the current policy landscape is drawn, the 'policy gaps' between the current EU policies and the endpoint of a climate neutral European energy system are investigated. A policy gap exists if current legislation is not sufficient to reach a climate neutrality in the EU. Based on interviews with experts, literature research and own analyses the main gaps in existing and planned policies related to transnational energy infrastructure are identified.

## 2.3 Policy instrument design

In this step, the core instrument *integrated infrastructure planning* for transnational energy infrastructure is specified and shaped, through literature research and interviews with experts. The gaps identified in the previous steps are used to shape policy options which will help reaching the goal of a climate neutral EU in 2050[2]. Different policy options for the core instrument are shaped, which are linked to the policy avenues. In this way, the impact of different policy options can be assessed to investigate the benefits and drawbacks of each option.

## 2.4 Impact assessment

In this step, the impact of the different policy options on several relevant criteria is assessed. For some relevant criteria, the impact of the policy option is assessed quantitatively, for others the impact assessment is qualitative.

The impact assessment of the different policy options of the core instruments consists of two parts:

1. **Impact of efficient realisation of transnational energy infrastructure.** In this part we assess the impact of reaching the goal: efficient realisation of transnational energy infrastructure. This gives insight in *why* efficient realisation of transnational energy infrastructure is necessary. The impact of transnational energy infrastructure on greenhouse gas emissions, societal costs and benefits and security of supply is determined. If possible, we assess the impact *quantitatively.* Otherwise, the impact assessment is qualitative.
2. **Impact of policy option on timely and efficient realisation of transnational energy infrastructure.** In this part we assess *how* the different policy options contribute to the goal: timely and efficient realisation of transnational energy infrastructure. In this part, we also discuss barriers to the implementation of the policy option, interaction with other relevant policy instruments, compatibility with long-term mitigation requirements and social and economical impacts. This part of the impact assessment is *qualitative*.

Firstly, the assessment framework is shaped more precisely. Literature research, expert judgement and tuning with the other case-studies in this work package is used to gather a list of relevant assessment criteria for both parts of the impact assessment. This list consists of general assessment criteria for policy instruments and assessment criteria specifically relevant for infrastructure.

After completion of the assessment framework, the impact assessment was performed. The assessment of the impact of timely and efficient realisation of transnational energy

[2] The policy options do not necessarily apply to all identified gaps. One of the main gaps in current legislation is chosen and the policy options are shaped to cover this gap

infrastructure is a general impact assessment which is not directly linked to the different policy options, but assesses the importance of proper planning of transnational energy infrastructure. The second part of the impact assessment, the impact assessment of the policy instrument itself, is performed for each of the policy options. The results of the assessment for each of the policy options are compared to assess the benefits and drawbacks op each option.

# 3. Climate neutral Europe: system analysis

This chapter provides the background and context for the case study on integrated infrastructure planning. We first describe how the European energy system[3] is expected to change between now and 2050. Next, we address the role transnational energy infrastructure can play in the future climate neutral energy system.

## 3.1 What does a climate neutral European energy system in 2050 look like?

The Climate Law, legally binding for the European Union as a whole, mandates the EU to be climate neutral by 2050. To achieve this objective, all sectors will have to undergo considerable transformation. The energy sector, and energy infrastructure as part thereof, is the enabler for other sectors to achieve climate neutrality.

The energy system in 2050 will be very different from the energy system now. The system changes can be summarised in five intertwined trends each with its own implications for the energy system:

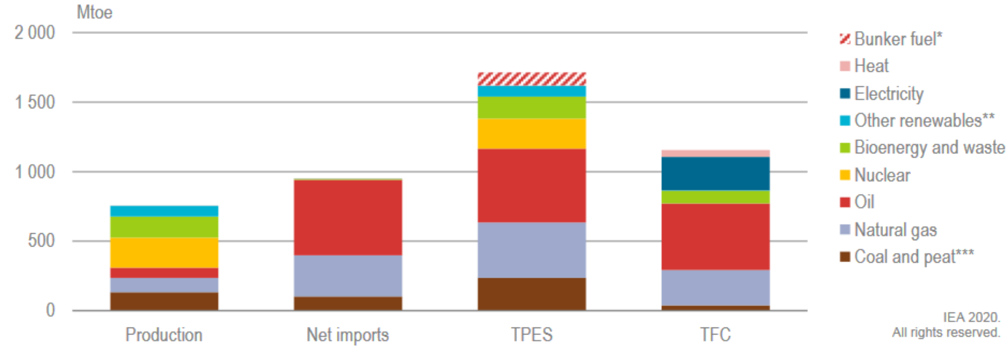
1. Lower overall energy demand.
2. Large share renewable energy production.
3. Changing roles of energy carriers.
4. Strong system integration.
5. Fewer energy imports from outside the EU.

We discuss these trends briefly one by one below.

### 3.1.1 Lower overall energy demand

The total energy demand is expected to decrease between now and 2050 due to significant improvements in efficiency in all demand sectors. Figure 1 and Figure 2 show that the recent energy demand in the EU 27 lies a little below 13,000 TWh. By 2050 the total demand is expected to decrease by a quarter to a third, to 8,500 TWh to 9,000 TWh (Entso-E & Entsog, 2022).

[3] The energy system consists of all elements related to production, demand, conversion, storage, import/export, and transport of energy.




The EU imports over half of total energy supply, in particular oil but also coal and gas.

**Bunker fuel* refers to oil products used in international bunkering (not part of the TPES).

***Other renewables* includes hydro, wind, solar, geothermal and tidal/wave/ocean.

****Coal and peat* includes oil shale.

Note: Mtoe = million tonnes of oil equivalent.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 1. Overview of the current EU energy system (IEA, 2020)[4]

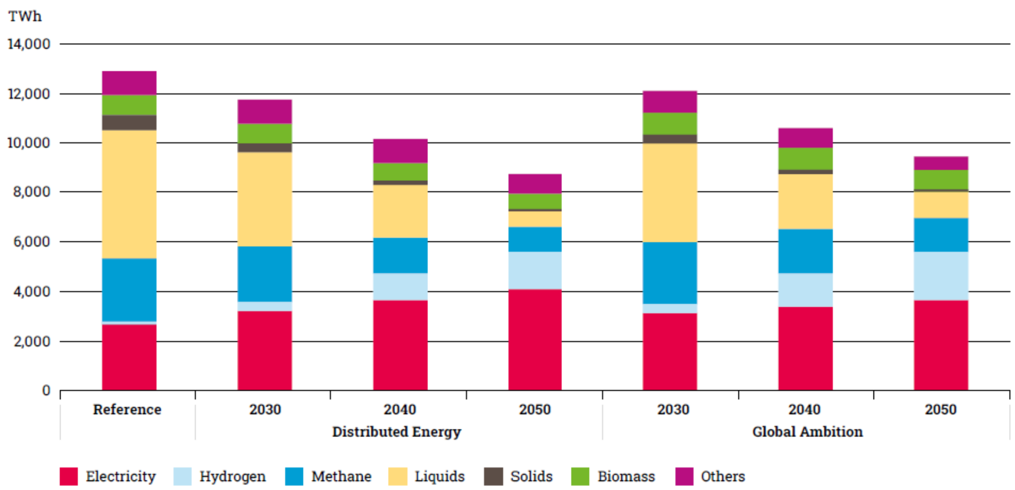



Figure 2. Final energy demand per carrier for the EU 27, for two different scenarios (Distributed Energy and Global Ambition) (Entso-E & Entsog, 2022)

Decrease in energy demand will be achieved both on the demand and supply sides. On the demand side the main efficiency measures are renovation and insulation of buildings, and use of more efficient technologies and electrification in all demand sectors. On the supply side the future system is expected to have lower losses through measures that support direct use of renewable electricity whenever possible and those supporting system integration, i.e., conversion of electricity to hydrogen whenever there is surplus of renewable power. Currently, substantial energy losses occur during conversion of gas or coal to electricity in powerplants. These energy losses will decrease when the share of renewable energy production increases.

[4] TPES = Total primary energy supply. TFC = Total final consumption.

### 3.1.2 Large share renewable energy production

The future energy system will primarily rely on renewable energy sources. The trio solar, wind, and biomass accounts for 60 to 80% of the total power generation mix in 2050 (see Figure 3). Nuclear, hydropower, imported hydrogen and small shares of other sources complete the mix.

For comparison, in 2021 (latest available data) 37.5% of electricity in the EU was produced with renewable energy sources (Eurostat, 2023). This is considerably more than the 2015 data shown in Figure 3. Yet, the role of electricity as an energy carrier is expected to grow significantly (see further in 3.1.3), requiring considerable further efforts to achieve the goals for 2030 and 2050.

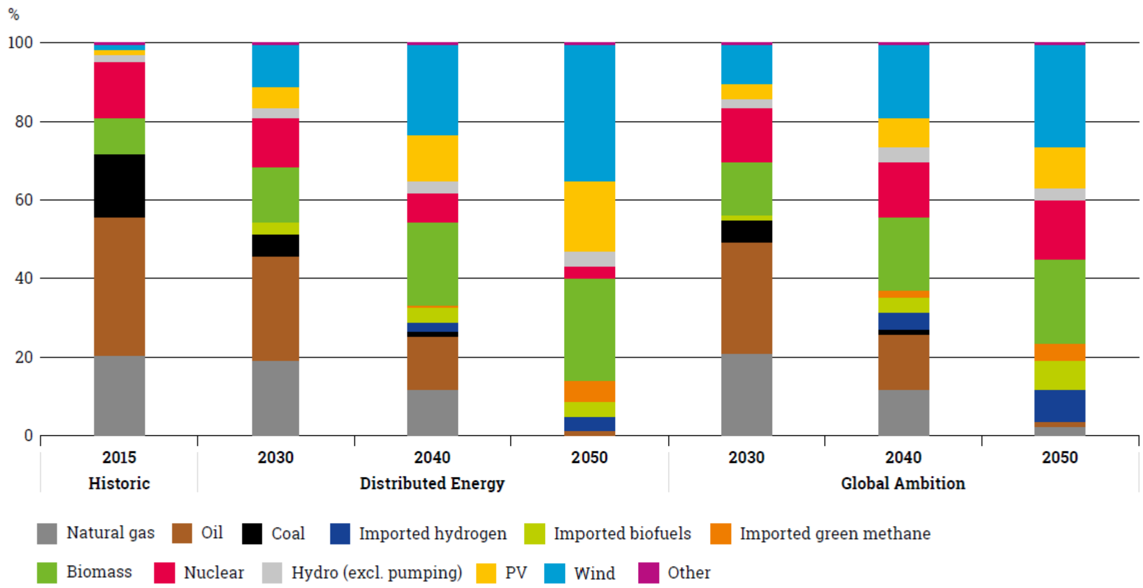



Figure 3. Power generation mix for the EU27 (Entso-E & Entsog, 2022)

The increasing share of renewable energy production in the electricity mix has two important effects on the future energy supply in the EU and the need for transnational energy infrastructure:

1. **Location**. The potential for renewable energy production depends on the local meteorological and geographical characteristics. This will lead to large differences within the EU. Some areas, like Southern Europe (solar PV) or Northwest Europe (offshore wind), have large potential for renewable energy production while other areas do not.
2. **Volatility**. The production of renewable energy sources depends on meteorological circumstances (mainly wind speed and solar availability). Currently, the main source of production of electricity are power plants which are demand-driven. With the increasing share of renewable energy production, the energy system in the EU will become supply-driven and supply will become more volatile.

### 3.1.3 Changing roles of energy carriers

The relative roles of different energy carriers are expected to change significantly. Currently, fossil fuels represent the largest share of the energy demand and oil is the main energy carrier in the energy system of the EU. Oil is responsible for approximately 40% of all total final demand (see Figure 1). Electricity currently accounts for about 20% of the total final demand (see also Figure 1).

By 2050 oil is expected to play virtually no role at all. Electricity will become the single most important energy carrier (accounting for 40 to 50% of the total demand), followed by hydrogen (accounting for approximately 20% of the total demand), (see Figure 2). Methane will likely still play a role in the energy system in 2050, however a smaller one than today. Natural gas is today the main source of methane and accounts for about 20% of the final demand (see Figure 2). In 2050 methane is expected to come from both natural gas (with carbon capture and storage) and for an important part from biomass (biomethane). However, its use is expected to more than halve: 1,600 TWh in 2050 compared to 3,800 TWh currently (Entso-E & Entsog, 2022).

Hydrogen is expected to grow from a marginal role as energy carrier today (see Figure 2) to the second most important one in 2050. Demand for hydrogen and its derivatives is expected to grow from 500 PJ/year in 2030, to 2,000 PJ in 2040, and 4,000 PJ in 2050 (Dnv, 2022). This growth is enabled by decreasing electrolyser technology CAPEX, which is expected to halve between 2020 and 2050 (Dnv, 2022).

### 3.1.4 Strong system integration

Solar and wind, and to a much lesser extent hydro, are variable resources. Their dominant role in the future energy system will require new electricity grid operation and energy system integration approaches. Both shortages and surpluses of renewable generation are expected in the future. They can be short- or long-term. Batteries are suitable to bridge short-term (minutes to hours) shortages in generation. Longer-term shortages (days to weeks) require other balancing approaches, one of which is hydrogen power plants. Surpluses can be similarly used to charge batteries or to generate hydrogen. In 2050 electrolysis (i.e., generation of hydrogen) is expected to account for approximately one third of the total electricity demand (Entso-E & Entsog, 2022), thus requiring a strong coupling between the electricity and the hydrogen systems.

### 3.1.5 Fewer energy imports from outside the EU

Energy imports in 2050 are expected to be much lower than today. Today the EU imports more than half of its energy as oil, coal, and gas (see Figure 1). In 2050 imports are expected to amount to 10% to 20% of the total energy demand, in the form of (green) hydrogen or hydrogen derivatives, (green) methane, and biofuels or biomass (see Figure 2).

The EU will however remain reliant on other countries for its energy supply as it will import raw materials and components for its energy system rather than energy carriers. All energy system components, such as solar panels, wind turbines, batteries, electrolysers, cables, pipes, etc. require raw materials that are not always available in the European Union. In view of its security of supply, the European Union seeks to diversify and secure its sourcing of these raw materials and energy system components through actions such as the Critical Raw Materials Act.

## 3.2 How much transnational energy infrastructure is necessary in a climate neutral energy system?

Given the aforementioned trends, in particular because of the increasing importance of renewable energy sources, the need for transnational energy infrastructure increases. This applies to both electricity and hydrogen infrastructure. It is expected that the role of fossil fuel infrastructure, like natural gas or oil pipelines, will decrease because of the phase out of fossil fuels (Amber Grid et al., 2022). The changing roles of energy carriers may also lead to an increase of heat infrastructure and possibly some new methane infrastructure because of biogas production, but it is expected that these infrastructures will be local and thus not relevant for this case study.

How much transnational energy infrastructure is necessary depends on how the transition to a climate neutral energy system will be shaped, in particular on choices regarding import of energy, use of energy carriers, and development of renewable energy sources. Generally speaking, over a broad range of scenarios for a climate neutral energy system in the EU, more interconnection between countries is desirable. Furthermore, further integration between electricity and hydrogen energy infrastructure is necessary. In the following sections we discuss the expected expansion of transnational energy infrastructure, for both electricity and hydrogen.

### 3.2.1 Electricity infrastructure

In the current European electricity infrastructure, substantial amounts of interconnections are already in place. The current electricity system in the EU has 93 GW of cross-border transmission capacity and until 2025 this capacity is expected to grow to 116 GW (Entso-E, 2022b). Mainly, Western European countries have strongly interconnected electricity systems. For example, the electricity system in the Netherlands will have more than 10 GW interconnection capacity in 2025 with several countries. Eastern European countries generally have less interconnections at the moment. The following figure shows the expected cross-border capacities in 2025.

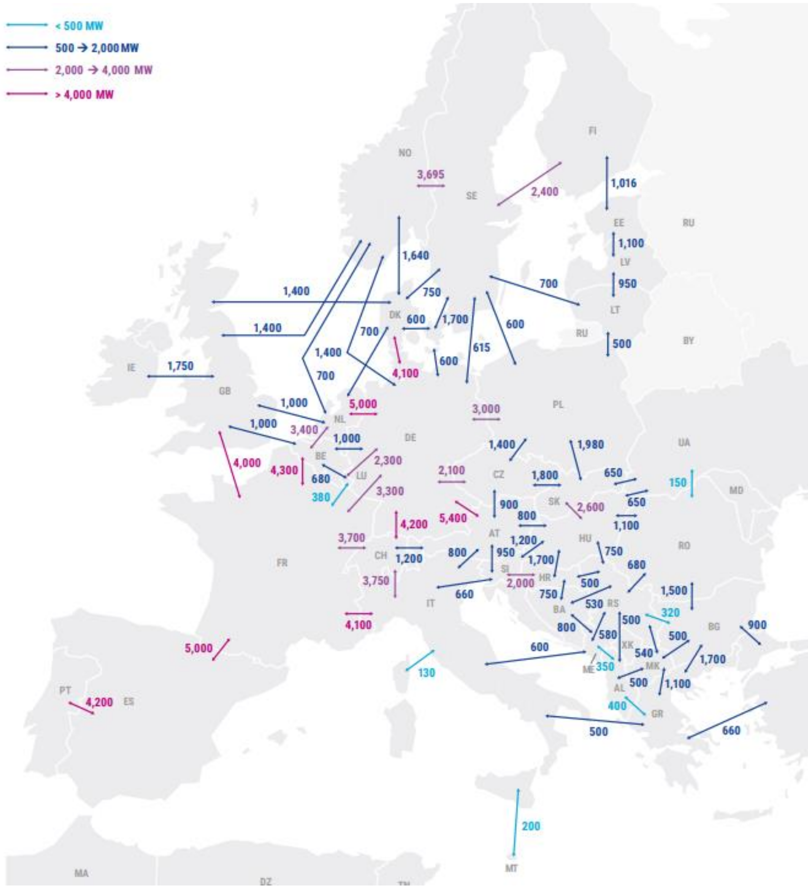



Figure 4. Expected cross-border capacities electricity infrastructure in 2025 (Entso-E, 2022b)

The growth of the production capacity of renewable electricity sources, mainly solar PV and wind turbines, and the electrification of the electricity demand leads to an increasing need for transnational electricity infrastructure. A more interconnected European electricity system can have several benefits like more efficient utilisation of renewable energy sources and lower total energy system costs (more in Section 6.2). Several studies have investigated what expansions of transnational energy infrastructure are necessary in the coming decades for an efficient European electricity system, by investigating different scenarios for the transition towards a climate neutral energy system. The outcomes of these different studies and assessments of different scenarios are similar, which means that the transnational energy infrastructure needs are quite robust (Arduin et al., 2022) (Entso-E, 2022b). In each of studies and scenarios, considerable expansion of the interconnection capacity is desirable.

Figure 5 gives an overview of the socio-economically cost-optimal amount of interconnection capacity in Europe in 2040 (Entso-E, 2022b). The total cross-border capacity increases with 88 GW after 2025 (Figure 4), this brings the total interconnection capacity to approximately 200 GW. According to the assessment by ENTSO-E, the interconnection capacity should increase in all of Europe. Apart from interconnections on land, also interconnections on sea near offshore wind power hubs are expected to arise.

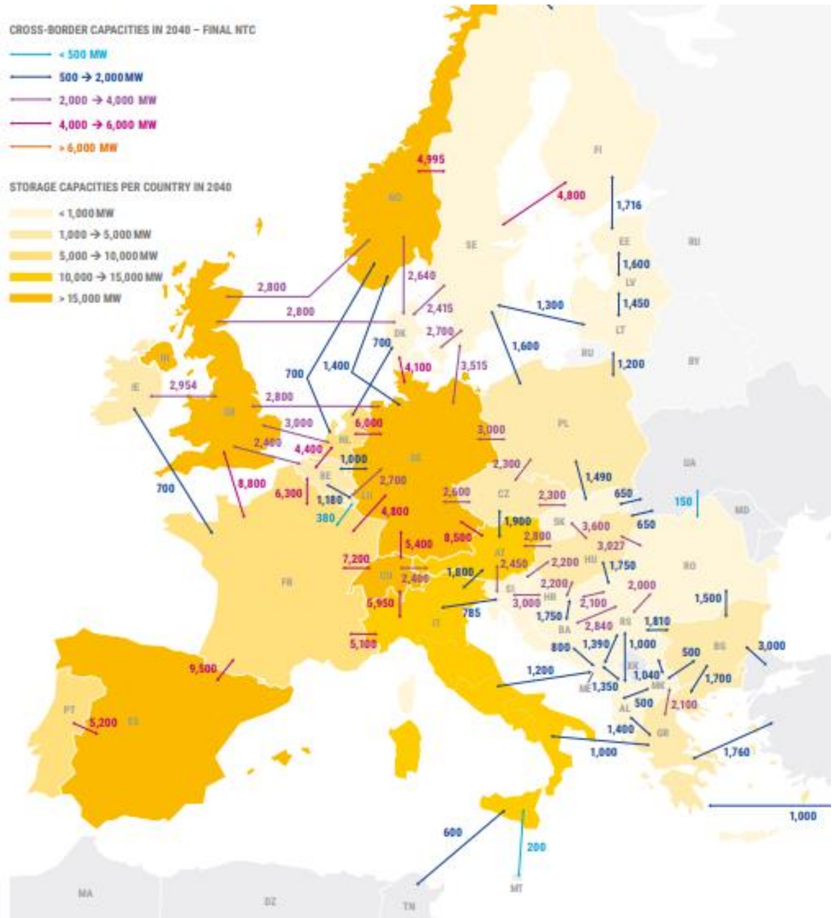



Figure 5. Optimal amount of interconnection capacity in 2040 (Entso-E, 2022b)

### 3.2.2 Hydrogen infrastructure

Currently, hydrogen is used in Europe in several industrial sectors like the ammonia sector and in refineries. Today, this hydrogen is mainly produced with fossil fuels (natural gas or coal). Some private hydrogen networks are present within some countries, but the total extent of hydrogen infrastructure in the EU is very limited.

In the future, the role of hydrogen in the energy system is expected to grow (see Section 3.1.5) and the hydrogen will have to be green (e.g., production with electrolysis using renewable electricity). Therefore, more hydrogen infrastructure will be necessary in the future. As natural gas will play a lesser and lesser role, much of the current natural gas infrastructure could potentially be reused for hydrogen transport. Some studies indicate that in 2050 hydrogen pipelines in Europe could be up to 80% repurposed natural gas pipelines (Carbon Limits & Dnv, 2021).

It is expected that the production of green hydrogen in the EU will be centralised in a few clusters with large potential for renewable energy production, like Southern Europe (solar PV) and the North and Baltic Seas (offshore wind). Furthermore, the import of green hydrogen will mainly take place at the borders of the EU (by pipelines) and in harbours (by maritime transport). A pan-European hydrogen network would enable the connection of regions with large potential for hydrogen supply with regions with large hydrogen demand (and limited potential for supply) through large transport corridors (Amber Grid et al., 2022).

Whilst the need for transnational electricity infrastructure is robust in different studies and scenarios, the need for transnational hydrogen infrastructure largely depends on several choices and developments towards a climate neutral energy system. The main factors impacting the total need for hydrogen interconnections are the development of renewable energy sources (size and location), the hydrogen demand in the EU (and the competition with other renewable energy carriers) and hydrogen import (size and location). However, several studies come to the conclusion that a pan-European hydrogen network will be feasible (Arduin et al., 2022) (Amber Grid et al., 2022). The specific needs for transnational hydrogen infrastructure, like the necessary capacity of the interconnections remains uncertain.

Figure 6 shows an idea for a possible configuration of a pan-European hydrogen network, developed by European gas transmission system operators (TSOs) (Amber Grid et al., 2022). The figure shows transport corridors from regions with large potential supply (the South of Europe and the North and Baltic Sea) to the centre of Europe and offshore hydrogen pipelines in offshore wind hubs. These transport flows align with findings from other studies (Arduin et al., 2022).

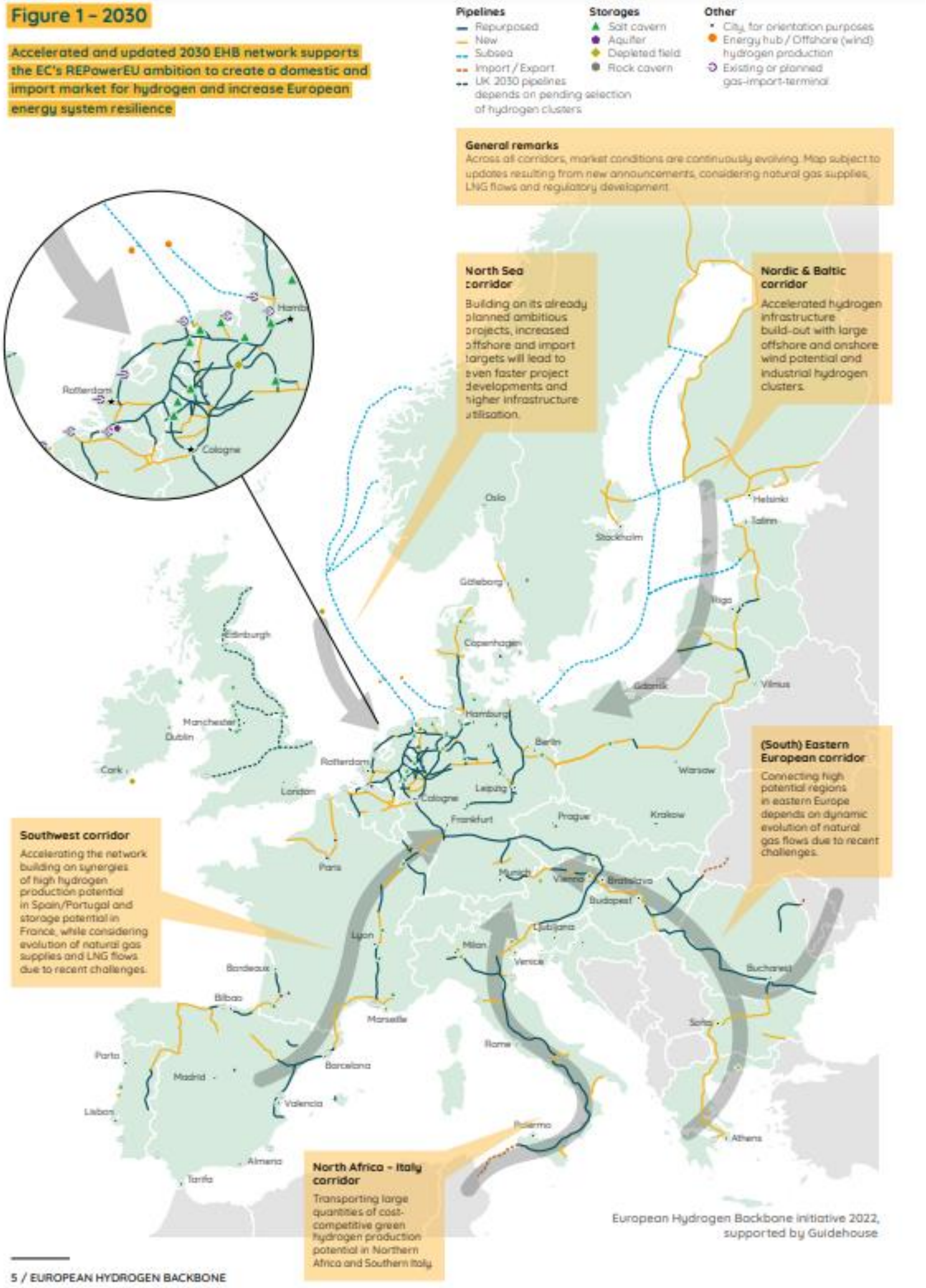



Figure 6. Possible pan-European hydrogen network (Amber Grid et al., 2022)

# 4. Current policies: overview and gaps

## 4.1 Overview of current EU policies on energy infrastructure planning

Only a few decades ago the natural gas and electricity systems were purely a national matter, but since then policies were increasingly developed at EU level. In this Section, an overview is given of the EU policies considering (cross-border) energy infrastructure that became more relevant in the last few decades. First, in Section 4.1.1 the development of EU directives and regulations on energy and energy markets is described as well as the current relevant policies. In Section 4.1.2 we zoom in on policies that are relevant specifically for the planning of energy infrastructure. In Section 4.2 we discuss which gaps exist in the current EU policies in the light of reaching a climate neutral European energy system.

### 4.1.1 EU internal energy policies

In this section, first the development of EU policies on energy and internal energy markets is described, followed by the current energy policies.

#### Historical development of EU policies on energy and internal energy markets

Over the last two to three decades the European internal markets for natural gas and for electricity have strongly developed. Coming from a situation where energy supply was purely a national (and public-owned) matter and were limited to the Member States' borders, gradually the various national markets were liberalised, harmonised and interconnections between them were established.

For electricity, the process of harmonising and integrating the national electricity markets started with the first Electricity Directive in 1996 (Florence School of Regulation, 2020b). For gas, the first Directive entered the stage two years later. In both cases, the directive laid the foundation for the liberalisation of the internal market (Florence School of Regulation, 2020a).

In 2003, a Second Energy Package followed, containing a second Electricity Directive (2003/54/EC), a second Gas Directive (2003/55/EC) and a Regulation on conditions for network access for cross-border electricity exchanges (1228/2003). This package built on the first directives, for instance by requiring legal unbundling of TSOs and allowing consumers to choose their electricity and gas providers. Also, Member States were required to create independent National Regulatory Agencies (NRAs) to oversee the energy markets (Florence School of Regulation, 2020a).

The Third Energy Package of 2009 further extended and deepened the European internal markets for natural gas and electricity. It included a new directive for electricity (2009/72) and for gas (2009/73), respectively, as well as a couple of regulations improving (cross-border) network access. Also, the package provided for the creation of the Agency for the Cooperation of Energy Regulators (ACER) (through Regulation 713/2009) and the European Networks for Transmission System Operators for gas (ENTSOG) and electricity (ENTSO-E), respectively. These organisations were meant to boost cross-border cooperation between both NRAs and TSOs.

The Third Energy Package initiated the development of so-called network codes for both the gas and the electricity market as well. Network codes are sets of technical rules that address the main barriers that impede the cross-border flow of gas or electricity, shaping the 'software' of the internal energy markets (the infrastructure being the 'hardware') (Florence School of Regulation, 2020c). While the Commission formally adopts the network codes, ACER and the ENTSOs play important roles in drafting them and overseeing their implementation at Member State level.

#### Current energy policies

In 2019, both the directive and regulation for electricity were revised, establishing Directive 944/2019 and Regulation 943/2019. Main updates included increased consumer protection and rights as well as active participation in the electricity market. Furthermore, flexibility is facilitated by updated rules on storage, demand response and aggregated participation in the energy market. Also, the cooperation of TSOs is further regulated by the establishment of so-called Regional Coordination Centres. There is a separate regulation on increasing the competences of ACER (Regulation 942/2019), specifically concerning issues with cross-border relevance. In this role, ACER will also have oversight on the Regional Coordination Centres (European Commission, 2023b).

In 2021, the Hydrogen and gas markets decarbonisation package was released, comprising of a review and revision of both the Gas Directive 2009/73/EC and the Gas Regulation 715/2009. Both legal documents are not yet in force, and during the time of writing agreement in the European Parliament still has to be reached. The proposed revision aims to facilitate the integration of renewable and low-carbon gases into the existing gas grid. Besides that, it contains EU-wide rules for the development of hydrogen infrastructure and a hydrogen market, as well as the establishment of the European Network of Network Operators for Hydrogen (ENNOH). The ENNOH will be entitled to manage the EU hydrogen network and facilitate the trade and supply of hydrogen across EU borders (European Commission, 2021).

### 4.1.2 Energy Infrastructure Policies

Considering the hardware of the transnational infrastructure, at European level there are several relevant policy documents. The Third Energy Package (2009) already included regulation on improving cross-border network access by creating the ENTSO (gas/electricity) entities and demanding them to develop a community-wide network development plan every two years, the so-called Ten-Year Network Development Plan (TYNDP), including scenario development. This was the first step in EU-wide policies concerning the planning of infrastructure.

In 2013, the TEN-E Regulation (Trans-European Network for Energy) was published, aiming to accelerate the development of strategically important infrastructure projects along priority corridors. This regulation describes the process of the selection, implementation and monitoring of so-called PCIs (Projects of Common Interest). In 2022 a review of the TEN-E Regulation entered into force, including an update of the priority corridors and changing the scope away from oil and natural gas, towards renewable energy sources and hydrogen (Florence School of Regulation, 2021).

In this section, the content of TEN-E Regulation is described, as well as the process of development of TYNDPs and the interaction between the two.

## TEN-E Regulation

The TEN-E Regulation came into force in 2013, as a means to accelerate the implementation of transnational infrastructure. The core of the regulation is to identify priority corridors and thematic areas for the roll-out of different kinds of infrastructure. The corridors and areas are selected in order to achieve energy policy objectives such as security of supply, functioning of the internal energy market, competitive energy markets and finally to achieve climate goals as set by the European Union. Individual projects that fit into these corridors or thematic areas can be identified as Projects of Common Interest (PCIs). The regulation describes the criteria as well as the benefits that are relevant for PCIs. It further contains rules on how the cost of PCIs is split over the relevant countries. The June 2022 update of the TEN-E Regulation brought it more in line with the energy transition goals of the European Union. The content of the TEN-E Regulation is described below (Commission, 2022).

### Priority corridors & Thematic areas

In the 2013 version of the TEN-E Regulation, priority corridors were pointed out for electricity, gas and oil infrastructures, while in the updated version focus is moved away from gas and oil towards hydrogen (including the use of electrolysers). Also there is more focus on the deployment of offshore renewable electricity generation and transport. Five offshore grid corridors are pointed out, while in the first version of the TEN-E Regulation there was only one. Besides the offshore corridors, there are three priority electricity corridors and three priority corridors for hydrogen and electrolysers in the updated version. There is a separate chapter focussing on the cooperation of Member States on goals for offshore renewable generation.

Next to priority corridors, there are thematic areas identified, which focus on a certain topic rather than a geographical area. In the updated TEN-E Regulation these thematic areas include smart electricity grid technologies, smart gas grid technologies and a cross-border $CO_2$ network.

## PCI/PMI provisions

While the region of priority corridors are identified in the regulation, it does not describe the exact location of where infrastructure should be built. However, the regulation does introduce the concept of PCIs (Projects of Common Interest): individual cross-border infrastructure projects that seem essential for one of the different priority corridors, and therefore will recieve support. The TEN-E Regulation describes the selection of the PCIs, which should be done following different criteria, amongst which a cost-benefit analysis. This cost-benefit analysis is performed by Regional Groups followed by an approval on Member State level. The different Regional Groups finally make regional lists of PCI projects. ACER has a monitoring role in the PCI selection process, mainly to make sure criteria, amongst which the cost-benefit analysis, are applied in a consistent manner.

The European Commission combines the regional lists into a 'Union list' after checking whether the projects are in accordance with the mandatory criteria for PCIs. Besides that, the EC should take into account the opinion of the Agency and of Member States and has to make sure the list contains a manageable number of projects. The Union list finally shall become part of the TYNDPs (Ten Year Network Development Plans) as established by the ENTSOs.

Once a project is selected as a PCI project, it enjoys facilitated permit granting and improved regulatory treatment. Some projects will receive funding from the Connecting Europe Facility (CEF) Fund, depending on the foreseen positive externalities of the project as well as financial aspects. The TEN-E Regulation describes the details of these support mechanisms as well as the implementation, monitoring, reporting, and evaluation procedure of PCI projects.

As an additional provision compared to the first version of the TEN-E Regulation, under the revision, besides PCIs, projects can also apply for a so-called PMI status (Project of Mutual Interest). A PMI is an infrastructure project between Member States and a third country outside of the EU, which are sustainable and able to demonstrate significant socioeconomic benefits at Union level and at least one third country. When complying with the criteria, PMIs enjoy the same treatment as PCIs and also can apply for CEF funding.

## Governance

In the updated version of the TEN-E Regulation, besides changes in the focus of priority corridors and projects, governance on a pan-European level is strengthened in order to improve the process of cross-border infrastructure planning. The European Commission is mandated to scrutinise or approve updates in the methodologies of the cost-benefit analysis of PCIs, and ACER may request updates and improvements on the methodologies as well.

The level of governance during the development of TYNDP (scenarios) is also strengthened. We elaborate on this in the next section.

## Ten-Year Network Development Plans

Since the establishment of the ENTSO entities in 2009 (as part of the Third Energy Package), they are required to develop a so-called Ten-Year Network Development Plan every two years. This plan is aimed at identifying necessary interconnections which are relevant from a commercial or security of supply point of view. The TYNDPs are non-binding, which means TSOs can decide for themselves what infrastructure to implement and don't necessarily have to realise the projects in the TYNDPs.

The TYNDPs are the result of two different processes. On the one hand, different scenarios for the development of supply and demand of energy in the EU (the TYNDP Scenarios) are explored in order to be able to define where additional transnational energy infrastructure would be feasible. From the scenarios, system needs are identified based on cost efficiency. On the other hand, infrastructure projects under development are collected and their performance under the different scenarios is assessed. The combination of system needs and projects under development results in the TYNDPs. ACER reviews the TYNDPs as well as the scenarios.

Since 2018, ENTSO-E and ENTSOG jointly develop their scenarios, even though the TYNDPs are still published separately. In the development of these scenarios stakeholders are involved in different stages. In the TYNDP Scenario report of 2022, there are three different scenarios: the National Trends scenario, Distributed Energy scenario, and the Global Ambition scenario. The National Trends scenario is based on existing national plans, the Distributed Energy scenario assumes decentralization and the Global Ambition scenario is based on globalisation meaning a focus on centralized investments and imports. Thus, a certain variation in the development of the energy system and consequentially the need for transnational energy infrastructure is included. The Distributed Energy and Global Ambition scenario are based on de EU climate goals for 2030 and 2050. However, changes in regulation on the planning of infrastructure compared to the current situation are not (explicitly) considered in these scenarios.

The updated TEN-E Regulation includes a few additional regulatory aspects on TYNDPs, which are relevant for future TYNDP (Scenario) reports:

- In the development of TYNDPs, a Union-level wide cost-benefit analysis shall be used.
- ACER will develop guidelines for the development of the TYNDP scenarios, that will be followed by the ENTSOs in developing those scenarios. There is also increased stakeholder involvement and the Commission is empowered to scrutinise and approve major steps in the development of the joint scenarios.
- Within the framework of the TYNDPs, the ENTSOs shall publish an *infrastructure gaps report,* identifying the gaps to reach the climate goals of the European Union of 2030 and 2050.
- ENTSO-e shall develop (also as part of the TYNDP) a separate plan for offshore network development.

- From 2024 on, hydrogen projects shall be part of the TYNDP for gas.
- From 2025 on, in the development of TYNDPs, integrated modelling shall be used based on consistent methodologies containing common assumptions.

## 4.2 What are gaps in the existing EU policies to reach a climate neutral European energy system?

In this section, we assess the existing policy gaps at EU level with regard to the infrastructure needs of a climate neutral European energy system. Firstly, we consider the gaps related to the realisation of sufficient transnational infrastructure, covering the cross-border integration of energy infrastructure. Secondly, we analyse the gaps concerning the integration of two energy carriers that are crucial for the climate neutral energy system, namely electricity and hydrogen.

### 4.2.1 Cross-border integration

#### The importance of an EU-level viewpoint for infrastructural planning

As indicated in Section 3.2, although the exact capacities of energy infrastructure will depend on certain choices like import dependency and use of the different energy carriers, all scenarios for a climate neutral European energy system indicate a need of increased cross-border interconnections. This applies both to electricity and hydrogen infrastructure. On the other hand, not all connection capacities across the border of any two EU member states need to be increased to the same extent. A system of high-capacity backbones and lower capacity branches at European level could ensure sufficient interconnections in an efficient way, without the need to enhance every single cross-border connection. Designing the most efficient infrastructure network would enable the realisation of a climate neutral energy system at European scale, while at the same time limiting as much as possible the investment costs and the time needed for implementation.

To realise this most efficient infrastructure network, it is necessary to plan the infrastructure at the European level. In the first place because of geographical considerations: an infrastructural network at European scale will not be designed in the most efficient way possible if it is a sum of bottom-up considerations fed by national interests. A full overview of demand, supply, import and export facilities, and existing infrastructure in the whole EU is needed to determine which connections need to be strengthened, while avoiding overinvestment. For instance, robust electricity corridors between wind farms at the North Sea towards high-demand sites in Central Europe may not be accounted for if the planning does not take place at a pan-European level. In the second place, also political considerations urge towards a European viewpoint: national interests may block or delay connections that are crucial for the infrastructure at EU-level. For instance, France has shown reservations against a hydrogen pipeline from the Iberian Peninsula towards Central Europe, fearing that it would negatively impact its opportunities to supply hydrogen based on nuclear power. However, from a pan-European perspective, the realisation of this pipeline may be efficient.

## The lack of an EU-level viewpoint as policy gap

Based on literature and a number of interviews with experts in the field, we have concluded that there is an underdevelopment of the pan-European viewpoint in the planning of infrastructure. Below, we explain this statement by illustrating a couple of aspects of current EU policies on energy infrastructural planning where this EU-level approach turns out to be underdeveloped. We discuss the TYNDPs, the TEN-E corridors and the PCI selection process, respectively.

### PCI status is not decisive

From the interviews we conducted, we concluded that the PCI status does not seem decisive for TSOs to include certain projects into their investment planning. This status is supportive in terms of public relations and the option to attract funding from the CEF, but other considerations are more important for TSOs in their decision-making process. This means there is no clear incentive for TSOs to design their projects in order to obtain a PCI status.

### PCI selection process lacks transparency

PCIs contribute to the realisation of the TEN-E corridors and thematic areas. Based mainly on the interviews we conducted, we conclude that the process through which the PCIs are selected lacks transparency and is prone to include political considerations. This means there is no guarantee that the projects that are assigned a PCI status are indeed the ones that are the most important ones in terms of creating the most efficient energy infrastructural network at EU level. Also, PCIs are selected at a regional level, hence the cost-benefit analysis accompanying the PCI proposals does not take into account the pan-European level of assessment and actually mostly focuses on the two neighbouring Member States involved in any cross-border connection project.

The Commission decides on the Union-wide PCI list, after Member States and other stakeholders have been able to comment through a public consultation. In reality, Member States have no incentive to critically reflect on projects in other Member States and will usually refrain from doing so, even if they might have doubts on the necessity of certain projects from the viewpoint of the EU-wide energy system. As the considerations of the Commission in selecting the final list are not public, it is not clear to what extent the PCI selection is in line with efforts directed at realising the most efficient energy infrastructural network in the EU.

### Ten Year Network Development Plans are non-binding

As described in Section 4.1.2, both ENTSOs are required to publish a TYNDP every two years. These plans contain requirements in terms of energy infrastructure for the next ten years for the entire EU, based on different scenarios and modelling results and taking into account the

European climate policy objectives. However, the TYNDPs are not binding in any way: the national TSOs have the complete decision power for infrastructure investments and are free to make use of the suggestions included in the TYNDP for their investment planning, or to disregard them. In reality, the assessment by the TSOs of what is needed in terms of new or enhanced connections will often coincide with the TYNDPs results, if only because the TSOs are involved in the process leading to the TYNDP scenarios. But in cases where the realisation of a new connection is mostly in the interest of the European infrastructure network as a whole, and less needed from the perspective of a national TSO, there is currently no guarantee that the TSO will include this connection into its investment plans, nor a way to force the TSO to do so. Furthermore, the current process is focused on the subsequent realisation of cross-border interconnections between two countries. Therefore, for the realisation of other types of infrastructure, such as supranational corridors between areas for large scale renewable energy production and high demand centres, many different TSOs would need to work together for each of the composing parts. This is not supportive for a swift implementation of these types of structures.

#### TEN-E Corridors are not designed for a climate neutral energy system

The main policy instrument for pan-European energy infrastructural planning currently is the TEN-E Regulation. It identifies a number of priority corridors for both electricity and hydrogen, and additionally a number of priority thematic areas. The corridors are mainly designed to integrate areas that are currently not well connected to the European energy markets and to enable the installation of increasing renewable energy capacity. Individual projects that fit into these corridors or thematic areas can be identified as Projects of Common Interest (PCIs).

Although the TEN-E Corridors can be expected to contribute to the infrastructural network needed for a climate neutral energy system, they are not designed to achieve this. Besides, while the electricity corridors indeed are described as corridors with a certain geographical limitation (for instance: north-south electricity connections in Western Europe), the hydrogen ‘corridors’ do not represent specific corridors but rather refer to interconnections in general in a certain area (for instance: hydrogen interconnections in Central Eastern and South Eastern Europe).

For these reasons, we conclude that the TEN-E corridors as a policy instrument, although helpful, are not sufficient to provide the necessary pan-European viewpoint for energy infrastructural planning at the necessary level of granularity.

### 4.2.2 Integration between energy carriers

As discussed in Section 3.1.2, both shortages and surpluses of renewable electricity are expected in the future. Hydrogen is seen as an important medium to overcome long-term shortages of electricity. For the production hydrogen, electrolysis will be an important proces, contributing to a substantial part of the electricity demand. The conversion of hydrogen into electricity and vice versa will take place at conversion hubs where the respective infrastructures meet. The amount of conversion has an impact on the need for electricity as well as hydrogen infrastructure, and thus the planning processes of both infrastructures should be coordinated and must be looked at in an integrated way.

The development of the TYNDPs for gas and electricity by the respective ENTSOs currently are not completely seperate processes, as some cooperation takes place, which is moreover increasing with time. Since 2018, ENTSO-E and ENTSOG do jointly develop and release the TYNDP Scenarios. Besides this, from 2025 integrated modelling is required by the EU. This will also include modelling of the hydrogen infrastructure, performed by the yet to be established ENNOH (Commission, 2022) (EC, 2021).

However, based on literature review, we have concluded that in the light of the energy transition there is a lack in integration of the planning of hydrogen and electricity infrastructures. There are still numerous uncertainties about the extent of cooperation between the different ENTSOs. First of all, the tasks of the ENNOH as well as how this entity will be shaped are yet to be defined. For now, ENTSOG is responsible for the development of Union-wide hydrogen network plans (EC, 2021). Besides that, the extent of cooperation between the different organisations is currently required only to a limited extent. Until today TYNDPs are submitted separately and there is no requirement for the future to submit an integrated TYNDP covering the different energy carriers. The required integrated modelling from 2025 entails the use of consistent methods based on common assumptions, but does not entail more specifications. In practice, this means only coordination is required but no drafting of an integrated development plan (Florence School of Regulation, 2022).

# 5. Policy instrument design

This chapter describes how the core policy instrument *Integrated Infrastructure Planning* can be designed as to remediate current policy gaps, as identified in the previous chapter. We first describe the general principles of the policy instrument design, building further on the previous chapter and answering the subquestion "How can the policy instrument integrated infrastructure planning be shaped to cover the current policy gaps?" Next, we apply these principles to the policy instrument according to the four[5] policy avenues and develop different options for the core policy instrument.

## 5.1 How can the policy instrument integrated infrastructure planning be shaped to cover the current policy gaps?

The main current policy gaps of the existing approaches to transnational infrastructure planning are the lack of a pan-European viewpoint and energy carrier integration. Transnational approaches such as PCIs and TYNDPs are efforts to transcend the national level in infrastructure planning. However, currently the decision-making processes applied in these approaches in practice don't guarantee that the 2050 objective of a pan-European climate neutral energy infrastructure is fully taken into account in investment planning. Current approaches are focussed on incremental increases of regional cross-border interconnections, are not always fully transparent, and do not have a pan-European system view at their heart. There is a tendency towards a national or regional focus instead of a pan-European one. Efforts are underway to bring a more European perspective into the process, for instance by requiring the ENTSOs to apply a European Cost Benefit Analysis (CBA) to the TYNDPs. This CBA is however informative and carries in practice no obligations for Member States or their TSOs. Current approaches thus do not have the full capacity to reap the benefits of a pan-European infrastructure view, such as higher system-wide cost-efficiency, lower back-up infrastructure requirements, and increased security of supply (more in Section 6.2). Also, the possible need for supranational structures in the future energy infrastructure system do not easily surface in the current planning processes. A new instrument for integrated infrastructure planning should therefore mend the fragmentation and regional or national inclination in transnational infrastructure planning, steering the cost-benefit analysis and decision-making to a pan-European level.

The main current gap as described above pertains to decision-making. Therefore, we focus the design of the policy instrument Integrated Infrastructure Planning on the applied level of governance. In the context of this study, this translates mainly to the policy level where decisions are made on investments in physical infrastructure. Governance of infrastructure requires a

[5] In fact, we distinguish three different varieties of the policy instrument that can be linked to three of the policy avenues, while the Degrowth Policy Avenue could make use of any of those three varieties.

specific approach due to the unique characteristics of infrastructure as an asset: its public nature, high construction costs and longevity.

These characteristics mean that governance of infrastructure lies with independently operating entities such as TSOs and regulators, as well as governments themselves. The main governance questions for the design of the policy instrument integrated infrastructure planning are (1) to determine at which level – national or European – the responsibilities for decision-making lie, and (2) which roles the TSOs, regulators, governments, and other parties play. The policy instrument options described below vary in who bears the responsibilities for planning, prioritising, deciding, and coordinating the transnational energy infrastructure. We discuss the unique infrastructure characteristics below, and indicate how we include them in the policy options.

### Public nature of infrastructure requires process transparency

Infrastructure is a public good, its existence and service level are of importance for society and economy at large. At the same time, infrastructure has considerable effects on communities and environments where it is constructed. Given the number of stakeholders and economic interests that infrastructure affects, decision-making for infrastructure planning is complex. In practice, projects are prone to long and untransparent decision-making processes, are often largely prepared as desk-studies with key decisions made behind closed doors. Local stakeholders are not always consulted in a timely manner, and remuneration for local losses is not always sufficiently considered. The policy instrument integrated infrastructure planning should include **process transparency, including local consultation**. It should thus deter corruption and prevent overweighing certain stakes. Process transparency here means that processes to achieve key decisions are made public, and include consultation of local stakeholders by design.

For each of the policy options below, we indicate who is responsible for process transparency and local consultation.

### Cost and longevity of infrastructure require EU-wide view and coordination

Infrastructure is expensive to build, it has long lead times and is long-lived. It therefore requires a **long-term, system- and EU-wide vision**. This requirement is already partly fulfilled by the European Union's ambition of a sustainable, climate neutral energy system in 2050. It however in addition requires **extensive coordination** when building transnational infrastructure in practice. Coordination needs to take place first and foremost across countries, to achieve the benefits of transnational infrastructure not only on the regional but on a European scale. In addition, coordination across energy carriers (electricity, methane and increasingly hydrogen) is also key.

For each of the policy options below we indicate how and to what extent the EU-wide vision is implemented. We further show who is the responsible entity for the coordination of transnational energy infrastructure development.

## 5.2 Which policy options of integrated infrastructure planning are possible?

We describe three different policy options to design the instrument integrated infrastructure planning. The policy options align with policy avenues from Task 1 of Work Package 4 (see Section 1.1). The three policy options differ in the level at which the decision-power and responsibilities lie. Firstly, we briefly summarise the three policy options, and elaborate on each of them in a dedicated section.

1. **Policy option 1 – Fragmented governance.** This policy option most closely resembles the current situation. The policy instrument is based on facilitation of collaboration between Member States, while leaving all responsibilities with the individual Member States and the TSOs operating within their borders. This policy option is most closely aligned with the Green Economic Liberalism Policy Avenue.
2. **Policy option 2 – Pan-European governance.** In this policy option the policy instrument is based on centralisation of governance. All responsibilities for planning, prioritising, deciding, and coordinating transnational infrastructure are transferred to a single European TSO, possibly a new incarnation of the current ENTSOs. This policy option is most closely aligned with the Green Industrial Policy Avenue.
3. **Policy option 3 – Middle-of-the-road.** Policy option 3 lies in between options 1 and 2. Here, the ENTSOs are given the responsibility to set out binding requirements for interconnection between Member States (e.g., X GW between countries A and B by 2040). The ENTSOs' requirements are based on pan-European system optimisation. Member States and their TSOs must adhere to these requirements, and bear the responsibility for the planning, governance and operation of the interconnections. This policy option is most closely aligned with the Directed Transition Policy Avenue.

We discuss infrastructure governance for Sufficiency and Degrowth separately. The Policy Avenue Sufficiency and Degrowth focuses on a goal – less consumption – rather than on means and pathways to achieve this goal. Degrowth can indeed be achieved through different roads. Infrastructure governance is therefore orthogonal to the Sufficiency and Degrowth Policy Avenue. Any of the policy options above can be applied to this paradigm.

### 5.2.1 Policy option 1 – Fragmented governance

The first policy option is the closest to the current situation. It primarily proposes improvements of the existing approaches, while retaining the governance for transnational energy infrastructure at the Member-State-level. Policy option 1 is best aligned with the Green Economic Liberalism Policy Avenue. The Green Economic Liberalism Policy Avenue is based on redirecting market forces and private initiative to drive the transition to climate neutrality. Realisation of transnational energy infrastructure is not entirely market-based, since it is a regulated activity. But in this policy option market forces play a relatively large role in the decision-making process, since the national TSOs make investment decisions based on (local) cost-benefit analyses for the individual projects.

*Table 3 Key characteristics policy option 1*

| **Policy option 1 – Fragmented governance** | |
|---|---|
| **Key policy characteristics** | ▪ Closest to the current situation<br>▪ Based on voluntary collaboration between Member States<br>▪ Continuation of PCIs and TYNDPs, with improvements |
| **Decision-making power investment transnational energy infrastructure** | Regional/national TSOs |
| **Policy Avenue** | Green Economic Liberalism Policy |
| **Role EU** | Facilitation of collaboration between Member States |
| **Role Member States and TSOs** | Full responsibility and governance |
| ***Process transparency, incl. local consultation*** | Entirely national level |
| ***Long-term, system- and EU-wide vision*** | Voluntary use of EU-level tools and data |
| ***Extensive coordination*** | Member States and TSOs enable activities of market parties |

In this policy option, integrated infrastructure planning is carried out by regional or national TSOs as is currently the case. There is no decision power on infrastructural investments at the EU level, but collaboration amongst the TSOs is facilitated through the ENTSOs and the stakeholder involvement in the development of scenarios for the TYNDPs. The TYNDPs remain non-binding, enabling TSOs to decide by themselves to what extent they make use of the TYNDP results in their investment planning. Furthermore, transnational energy infrastructure projects can still get the PCI status and receive the related benefits, to stimulate efficient cross-border infrastructure investments. The practice of PCI development is improved by making the decision-criteria more objective and transparent. Although currently objective criteria (of which the main is a cost-benefit analysis) are used in the PCI selection process, the European Commission has a final saying in which projects will obtain the PCI status. This decision-making process leading to a so-called 'Union-list' of PCI projects is currently not transparent. In policy option 1 this process becomes more transparent and objective, for instance by requiring the Commission to publish its considerations.

Figure 7 shows the decision-making process for transnational energy infrastructure and the roles of different entities with this policy option.

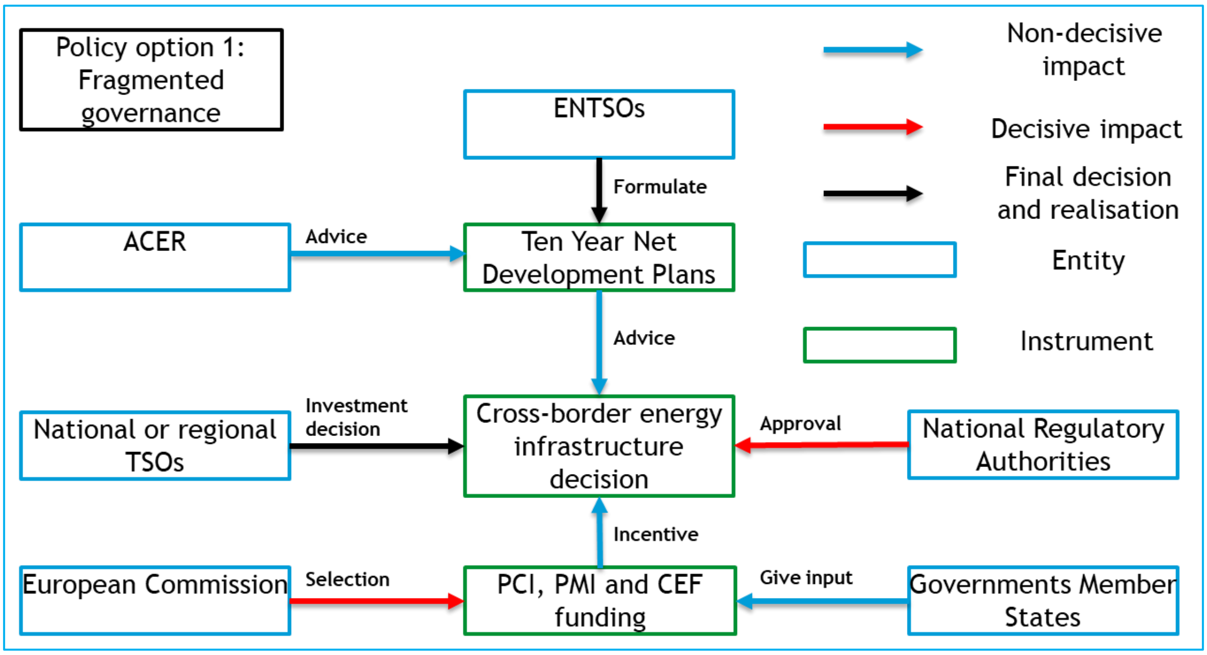



Figure 7. Overview governance structure policy option 1: Fragmented governance

In the context of the Policy Avenue Green Economic Liberalism, integrated infrastructure planning is seen as an enabler for the activities of market parties. EU-level data and information are used as tools and supplementary material. Financing of transnational infrastructure projects remains with the national TSOs, without new EU-level provisions for their funding. TSOs or the national governments can decide on the use of either public funding, subsidies or private investments for transnational infrastructure projects. There are no EU-level requirements to integrated energy carriers under the umbrella of one TSO. Governance of different energy carriers (electricity, natural gas, hydrogen, etc.) is thus left to the individual Member States. The regulatory arrangements remain as they are now, with national regulators remaining the responsible regulating authority for transnational energy infrastructure investments and ACER retaining its current (limited) responsibilities.

The key infrastructure characteristics in this policy option are fulfilled as follows:

- **Process transparency, including local consultation.** As all governance responsibilities lie with the individual Member States and their TSOs, they are also responsible for process transparency and local consultation. There are no new EU-level process requirements. Financial remuneration of local communities can be an important means within this market-oriented paradigm to enable the construction of transnational infrastructure. Member States, their TSOs and national regulators are responsible to ensure process transparency.
- **Long-term, system- and EU-wide vision.** The long-term, system- and EU-wide vision is developed at the European level without incurring binding requirements on national TSOs, similarly to the current situation. The EU stimulates efficient cross-border

infrastructure investments by granting projects PCI status and facilitates the collaboration and sharing of information between Member States. The European Cost Benefit Analysis (CBA) is continued in this policy option and is used in the PCI procedures and for the development of the TYNDPs. TYNDPs and corresponding scenarios, templates and datasets are made available and can be voluntarily used by Member States, their governments, TSOs and regulators, but have no binding elements.

- **Extensive coordination.** Market parties expect Member States and their TSO to enable their bottom-up demand for integrated infrastructure. In the Green Economic Liberalism Policy Avenue, market forces are redirected to invest in sustainable generation, storage, and conversion. They seek the most cost-effective methods and locations to invest. Geographical price differences drive investments, in turn steering demand for interconnection. The Neoclassical environmental economics paradigm argues that the market-based allocation of resources and the coordination of production and consumption via price signals is superior to other forms of coordination. A key coordination challenge for Member States and the EU is therefore carefully designing the right market incentives in this Policy Avenue in general. As infrastructure is not a market activity, the main coordination challenge for the policy instrument integrated infrastructure planning is correctly and timely identifying and responding to the demand for transnational infrastructure by the market parties. This responsibility lies entirely with Member States and their TSOs.

### 5.2.2 Policy option 2 – Pan-European governance

The second policy option is the most transformative in terms of decision-making. The responsibility and implementation for planning, building and operating transnational infrastructure is entirely transferred to the European level. This policy option aligns best with the Green Industrial Policy Avenue. This Policy Avenue assumes the centralisation of power and financial resources in strong EU institutions, in order to overcome barriers to swift implementation of climate policies, such as long coordination processes and vested (local) economic interests. This centralisation allows for state-guided interventions, supports public investments and actively builds a green economy to achieve climate neutrality.

For energy infrastructure, policy option 2 hinges on the creation of a new European system operator, who is responsible for interconnections between countries, both in terms of transnational links between national grids and the creation of a supranational supergrid (e.g., a 500 kV DC electricity grid, and the pan-European hydrogen grid). We define this new entity as the Interconnection Systems Operator, or ISO. ENTSO-E, ENTSOG and ENNOH will merge into this new entity.

*Table 4 Key characteristics policy option 2*

| Policy option 2 – Pan-European governance | |
|---|---|
| **Key policy characteristics** | ▪ Most transformative policy option<br>▪ Fully European governance and responsibilities<br>▪ European Interconnection Systems Operator (ISO)<br>▪ Full integration of energy carriers within the ISO |
| **Decision-making power investment transnational energy infrastructure** | Pan-European ISO |
| **Policy Avenue** | Green Industrial Policy Avenue |
| **Role EU** | Centralisation of governance: ISO bears all responsibilities for transnational infrastructure |
| **Role Member States and TSOs** | TSOs responsible for national networks, ISO for interconnections and supranational supergrid |
| ***Process transparency, incl. local consultation*** | Entirely European-leel, ISO will require local support |
| ***Long-term, system- and EU-wide vision*** | Centralised view and mandate with the European ISO |
| ***Extensive coordination*** | Primary agency with the ISO, needs collaboration with TSOs |

The ISO is responsible for the integrated transnational energy system, and therefore oversees the interconnections and supranational grids for electricity and hydrogen. The ISO makes a pan-European techno-economical analysis to determine whether existing grids only need to be further connected by local interconnections and/or whether an additional supergrid is necessary. This holistic system responsibility cements the pan-European view on the energy system within one entity. The ISO makes EU-wide cost-benefit analyses for the entire European energy system, plans the interconnections and/or the transnational supergrid, and carries out the entire construction process from design and planning over construction to maintenance and operation. The ISO collaborates with national TSOs in a similar manner as TSOs currently collaborate with DSOs, since the transnational energy infrastructure has to be connected with the national energy infrastructure. To oversee the ISO the role of the regulator, ACER is significantly expanded, on par with the role of the national regulating authorities in national energy infrastructure investments. Figure 8 shows the decision-making process for transnational energy infrastructure and the roles of different entities with this policy option.

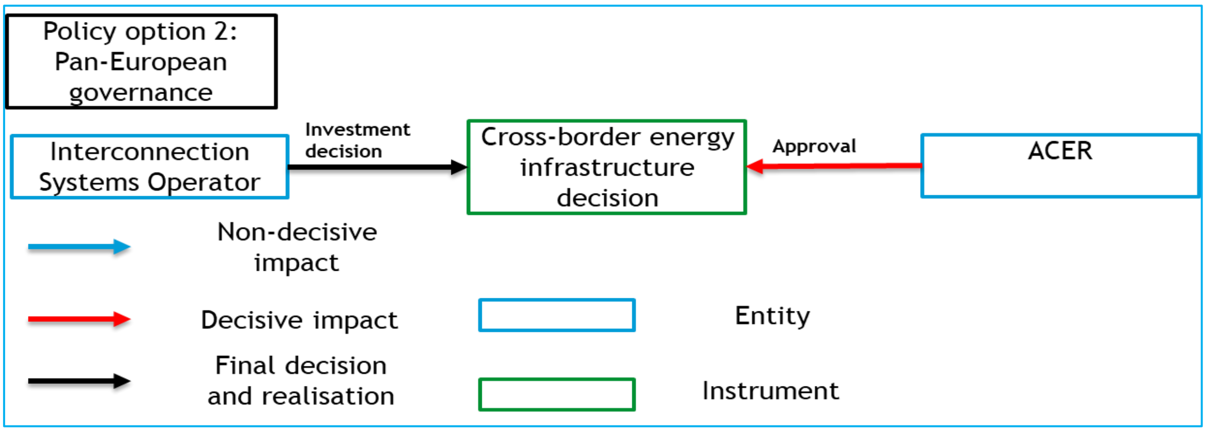



Figure 8. Overview governance structure policy option 2: Pan-European governance

Given that both the ISO and ACER are independent entities, they will require their own financing and have to receive funding. The ISO will require significant funding to be able to make the required investments in transnational energy infrastructure. These investments can be funded in several ways. One possibility is to align the method of funding of the ISO with the methods of funding of TSOs, i.e., by socialising the costs and charging all end-users of energy. The exact specifics of the funding base would need to be further elaborated if this policy option would come into being.

The key infrastructure characteristics in this policy option are fulfilled as follows:

- **Process transparency, including local consultation.** The governance of transnational infrastructure lies entirely with the European Interconnection System Operator. The ISO is thus entirely responsible for process transparency and local consultation. As the ISO is a highly centralised, European entity, it must seek local partners to adequately assess the local situation. As interconnections are planned and build in collaboration with TSOs, the TSOs are the most straightforward local partners. ACER and the European Commission can formulate additional requirements with respect to process transparency, local consultation and local remuneration.
- **Long-term, system- and EU-wide vision.** The single European ISO, responsible for the supranational grid and the transnational interconnections between national grids for the different energy carriers (electricity and hydrogen) has both the long-term system-wide perspective and mandate at the EU-level. The political and governmental institutions of the EU, like the European Commission, are responsible for the vision of the development of the energy system as a whole. They develop a vision on topics like the deployment of renewable energy sources within the EU, use of energy carriers and the import-dependency for energy. The ISO develops the transnational energy infrastructure that is necessary for the realisation of this vision for the future energy system. The European Cost Benefit Analysis (CBA) is an important tool to assess which investments in

transnational energy infrastructure are necessary. The outcomes of the European CBA are direct input for investment decisions.

- **Extensive coordination.** To plan, oversee and implement the transnational interconnections for the different energy carriers (electricity, hydrogen), the ISO needs to extensively collaborate and coordinate with a broad range of stakeholders in the entire European Union. The ISO will thus take up a pivotal role in the information and collaboration web. This role requires strong interdisciplinary and technical and public relations expertise within the ISO. The ISO plays a key part in ensuring security of supply within the entire European Union, bolstering the benefits of integration across energy carriers. Specific attention is necessary for coordination of the ISO with the national TSOs, since the transnational energy infrastructure is linked to the national grids, and with local authorities within Member States for the realisation of the transnational energy infrastructure on their territory.

### 5.2.3 Policy option 3 – Middle-of-the-road

This policy option lies between policy options 1 and 2 in terms of centralisation of competences and responsibilities for decision-making. A mandatory framework is set out at the European level. Member States and their TSOs have the responsibility to build transnational infrastructure within this framework. The framework is operationalised by the ENTSOs, who are given the responsibility to set out requirements for interconnection between Member States, for instance X GW between countries A and B by 2040. The requirements by the ENTSOs are based on pan-European system optimisation with a European Cost Benefit Analysis (CBA).

*Table 5 Key characteristics policy option 3*

| **Policy option 3 – Middle-of-the-road** | |
|---|---|
| **Key policy characteristics** | ▪ In between policy options 1 and 2<br>▪ Strengthening of ENTSOs and ACER<br>▪ European framework by ENTSOs, implementation by TSOs |
| **Decision-making power investment transnational energy infrastructure** | National/regional TSOs (within binding requirements from ENTSOs) |
| **Policy Avenue** | Directed Transition Policy Avenue |
| **Role EU** | Framework: Capacity and timeline requirements |
| **Role Member States and TSOs** | Implementation of requirements by TSOs |
| ***Process transparency, incl. local consultation*** | National governance: responsibility for process and consultation |
| ***Long-term, system- and EU-wide vision*** | Centralised view through ENTSOs framework |
| ***Extensive coordination*** | Coordination between ENTSOs and TSOs (Member States) |

Member States and their TSOs can chose the locations and other specifics of the transnational interconnection, and bear the responsibility for the planning, investments, governance and operation of the interconnections. This policy option is best compatible with the Directed Transition Policy Avenue, in which governments provide guidance for market parties through targets, standards and funding. Infrastructure is a public asset and only partially subject to market conditions, yet similar European-level guidance applies in this Policy option to the Member States and their TSOs.

To provide the strong European framework for this policy option, the positions of the ENTSOs and ACER are strengthened, and their funding is expanded. The ENTSO-E, ENTSOG and ENNOH intimately collaborate across energy carriers, yet are not necessarily merged into one entity in this policy option. The ENTSOs and ACER respectively set and regulate the framework within which national governments and TSOs make their decisions. The ENTSOs build further on the existing practices of the European Cost-Benefit Analysis and the TYNDPs. They indicate the need for transnational interconnection in terms of capacity (e.g., X GW) connected by a certain deadline (e.g., additional connection of X GW between countries A and B by 2040). The ENTSOs can also force the development of a possible supranational supergrid (e.g., a 500 kV DC electricity grid, and the pan-European hydrogen grid). However, this supranational supergrid would have to be realised by a number of Member States and their TSOs. It is up to the Member States and their TSOs to determine the locations and the specifics of these transnational interconnection. The following figure shows the decision-making process for transnational energy infrastructure and the roles of different entities with this policy option.

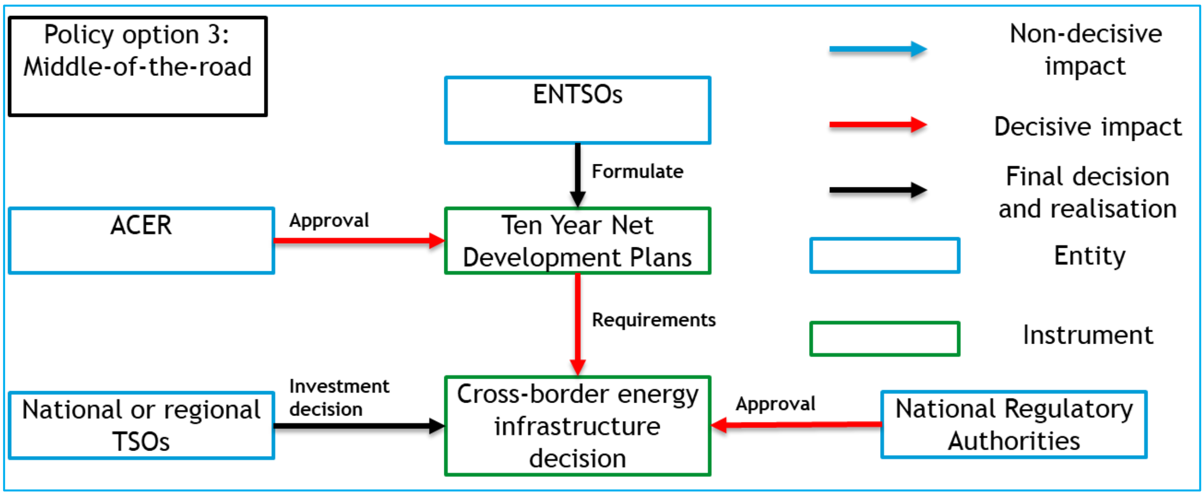



Figure 9. Overview governance structure policy option 3: Middle-of-the-road

In this policy option, the European Commission does require the Member States (through their TSOs) to fulfil the interconnection requirements set out by the ENTSOs. The European CBA and TYNDPs thus become mandatory guides rather than informational and non-binding guidelines. In contrast to policy option 2, the realisation of transnational infrastructure remains the responsibility of national TSOs, all the assets remain property of the national TSOs. The ENTSOs thus do not invest themselves in transnational infrastructure, i.e., they do not own or operate any physical assets. They do however need more formal competences, more personnel, and hence more financing than in the current situation to enable them to fulfil their role independently from the national TSOs. Similarly to policy option 2, the ENTSOs and ACER have to receive funding. However, less funding is necessary for these entities compared to policy option 2 since the investments in transnational energy infrastructure are made by TSOs. The exact specifics of the funding base will need to be further elaborated.

The key infrastructure characteristics in this policy option are fulfilled as follows:

- **Process transparency, including local consultation.** While the framework is set out at the European level, most of the decision-making process for transnational infrastructure lies with Member States and their TSOs. Hence, process transparency and responsibility for local consultation is largely similar to the situation in policy option 1. There is however an important difference in that the existence of the European framework in this policy option does not allow Member States to forego transnational interconnection in face of local opposition. Similarly to policy option 2, ACER and the European Commission can formulate additional requirements with respect to process transparency, local consultation and local remuneration.
- **Long-term, system- and EU-wide vision.** As in the other policy options, the political and governmental institutions of the EU, like the European Commission, are responsible for the vision of the development of the energy system as a whole. They develop a vision on topics like the deployment of renewable energy sources within the EU, use of energy carriers and the import-dependency for energy. In this policy option, the ENTSOs are responsible to translate this vision into concrete transnational interconnection requirements (in terms of GW by a certain deadline). The system approach needs to come from the intimate collaboration between the different ENTSOs, or their potential unification. Requirements for collaboration or potential unification can be imposed by the European Commission in this policy option.
- **Extensive coordination.** This policy option requires a delicate coordination balance between on the one hand the European level, represented by the ENTSOs and on the other hand all the Member States and TSOs who need to agree on, plan and implement the requirements set out by the ENTSOs. The division of responsibilities between both the European and the national levels can make this coordination challenging in practice.

## Infrastructure governance for Sufficiency and Degrowth

Infrastructure governance is orthogonal to the Sufficiency and Degrowth Policy Avenue. Any of the above policy options can be applied to this paradigm. The main effect of the degrowth paradigm on energy infrastructure, is that overall less energy is used and produced. Lower energy consumption means that less infrastructure is required as compared to other paradigms. However, transnational infrastructure is likely to remain necessary. Also with lower energy requirements, the role of renewable energy sources and renewable energy carriers (electricity and hydrogen) will increase and security of energy supply remains key to functioning of society. Therefore, also with the Sufficiency and Degrowth Policy Avenue additional transnational energy infrastructure will be necessary. The main difference with the other policy avenues is that given the degrowth paradigm the scale of interconnection in terms of capacity (GW lines and pipes) will likely be considerably lower. The governance to plan for the remaining necessary transnational infrastructure can lie at any of the levels described above.

# 6. Policy instrument: impact assessment

In the last chapter, different options for the core policy instrument *Integrated Infrastructure Planning* were introduced. In this chapter, we assess the impact of the policy options on several relevant criteria. For some relevant criteria, the impact of the policy instrument is assessed quantitatively, for others the impact assessment is qualitative.

It is difficult to quantify the effects of the policy options on the actual realisation of transnational energy infrastructure, but it is possible to quantify the effects when the transnational energy infrastructure is realised timely and efficiently. Therefore, the impact assessment of the different configurations of the core policy instrument consists of two parts:

1. **Impact of efficient realisation of transnational energy infrastructure.** In this part assess the impact of reaching the goal: efficient realisation of transnational energy infrastructure. This gives insight in *why* efficient realisation of transnational energy infrastructure is necessary. The impact of transnational energy infrastructure on greenhouse gas emissions, societal costs and benefits and security of supply are discussed. If possible, we assess the impact *quantitatively*. Otherwise, the impact assessment is qualitative.

2. **Impact of policy instrument on timely and efficient realisation of transnational energy infrastructure.** In this part assess *how* different configurations of integrated infrastructure planning will contribute to the goal of the instrument: timely and efficient realisation of transnational energy infrastructure. In this part, we also discuss barriers to the implementation of the policy instrument, interaction with other relevant policy instruments, compatibility with long-term mitigation requirements and social and economical impacts. This part of the impact assessment is *qualitative*.

Firstly, we will discuss the assessment framework in Section **Fout! Verwijzingsbron niet gevonden.**. In the assessment framework we will discuss the relevant assessment criteria for both parts of the impact assessment and we will discuss how we will assess the impact for these criteria. In Sections **Fout! Verwijzingsbron niet gevonden.** and **Fout! Verwijzingsbron niet gevonden.**, the actual impact assessment is performed.

## 6.1 Assessment framework

In the assessment framework we determine the relevant criteria for the impact assessment. We will discuss the relevant assessment criteria for both parts of the impact assessment. The relevant criteria can be criteria specific for energy infrastructure, but also general criteria to assess the impact of all types of policy instruments. For each criterion, we will mention which aspects will be considered in the impact assessment.

### 6.1.1 Impact of efficient realisation of transnational energy infrastructure

The following table gives an overview of the criteria which are used to assess the impact of efficient realisation of transnational energy infrastructure. We will specify whether we will assess these criteria qualitatively or quantitatively. These criteria are based on research from ENTSO-E (Entso-E, 2022b), FTI consulting for Ofgem (Fti Consulting, 2020) , Aurora Energy Research (Aurora Energy Research, 2020) and an EU impact assessment (EC, 2020).

*Table 6 Criteria assessment impact transnational energy infrastructure*

| Assessment criteria | Aspects considered | Assessment form |
|---|---|---|
| Overall energy cost | Effect on the overall electricity production cost, also sometimes named Socio-economic welfare (SEW) | Quantitative |
| Investment needs transnational energy-infrastructure | Investments are necessary for transnational energy infrastructure | Quantitative |
| Utilisation renewable energy production | With efficient transnational integration of energy infrastructure, the available renewable sources in the EU may be used more efficiently and less energy has to be curtailed or stored | Quantitative |
| Gas-based production and back-up power required | With efficient transnational integration of energy infrastructure, less back-up power from dispatchable power plants is necessary | Quantitative |
| Reduction greenhouse gas emissions | More utilisation of renewable energy production in the EU may lead to a reduction of $CO_2$ emissions | Quantitative |
| Security of supply | Transnational integration of energy infrastructure increase the security of supply for energy of individual member states and less loss of load | Qualitative |

In literature several other criteria can be identified which are not included in our scope. These criteria have a smaller effect and/or could not be determined quantitative or qualitative in this study. These criteria are: grid losses, energy system resilience/flexibility, learning by doing (cost price reduction due to more realisation), residual environmental and societal impacts and long-term lock-in.

### 6.1.2 Impact of policy instrument on timely and efficient realisation of transnational energy infrastructure

The following table gives an overview of the criteria which is used to assess the impact of policy options on timely and efficient realisation of transnational energy infrastructure. The impact of all these criteria is assessed qualitatively.

*Table 7 Criteria assessment impact policy instrument*

| Assessment criteria | Aspects considered |
|---|---|
| Effectiveness of policy instrument | How does the policy instrument make sure that an efficient selection of cross-border energy infrastructure will be realised? |
| Speed of transition | Timely realisation of energy infrastructure is a significant bottleneck in the energy-transition. How does the policy instrument make sure that the required transnational energy infrastructure is realised timely? How does the policy instrument affect the risk that the required energy infrastructure is not realised timely? |
| Transformative impact/compatibility with long-term reduction goals | To which extent is this core instrument expected to deliver a transformative impact? Is the policy instrument compatible with climate neutrality in the EU? |
| Barriers for implementation | What are the barriers for implementation, e.g., institutional barriers? |
| Interaction with other policy instruments | How does the policy instrument interact with other policy instruments and how may this affect the effectivity? |
| Social impacts | What is the impact on health, socio-technical transition processes and social and distributional aspects, including the gender dimension? |
| Economic impacts | What is the impact on productivity, competitiveness and employment? |

## 6.2 Assessment impact of timely and efficient realisation of transnational energy infrastructure

In this impact assessment we will determine the effects of efficient realisation of transnational energy infrastructure. The impact assessment consists of comparing two conceptual scenarios:

1. **Assumed autonomous development transnational energy infrastructure**: Based on literature we assume an increase of transnational energy infrastructure of maximum 50% until 2050.
2. **Societal optimal development transnational energy infrastructure**: The optimal amount of transnational energy infrastructure based on the total societal cost and benefits the model calculates (estimated with the PyPSA model, see text box).

These two conceptual scenarios are assessed with findings from literature and illustrated by a basic energy system modelling with the PyPSA model (see text box).

The overall results for the different criteria give an indication of the total societal cost and benefits of efficient realisation of transnational energy infrastructure. In our analysis we determine the effects of additional transnational infrastructure in 2050. The timely realisation of this infrastructure is expected to have the same positive and negative effects, however, is not specifically researched here.

**Energy system modelling with PyPSA**

To illustrate the findings form literature we performed some basis energy system modelling with the open source PyPSA-Eur-Sec model: A Sector-Coupled Open Optimisation Model of the European Energy System. PyPSA-Eur-Sec is described by the developers as "*an open model dataset of the European energy system at the transmission network level that covers the full ENTSO-E area. The model is suitable both for operational studies and generation and transmission expansion planning studies*".

The energy system modelling and analysis performed for this study was not extensive and serves only for illustrative purposes. For this purpose, a fully renewable energy system in 2050 is assumed with 100% $CO_2$ reduction compared to 1990. It is assumed that the current gas transmission infrastructure could be repurposed for hydrogen transport. Hydrogen imports are not considered. Fossil fuels are still available in combination with carbon capture and storage.

In the modelled scenarios only one parameter is varied: the allowed transmission line volume expansion (for electricity). This parameter is varied between 50% expansion and optimal expansion (somewhere between 200 and 300% expansion) compared to the current transmission line volume. Since we study the impact of one parameter on the energy system, the exact configuration of the modelled energy system is not crucial to illustrate the relative effect of optimal transnational energy infrastructure on the assessed impact parameters of this case study.

### 6.2.1 Overall results impact assesmment

The overall results are displayed in Table 8. We conclude that the realisation of additional transnational infrastructure can have a significant societal benefit. It requires additional investment in the infrastructure, however results in lower electricity generation cost, less curtailment of renewable energy and increase in security of supply. However there is a societal optimum. Investment in transnational infrastructure beyond this societal optimum will result in insufficient economical-societal returns for the required infrastructure investments. This emphasis the need for proper planning of transnational energy infrastructure.

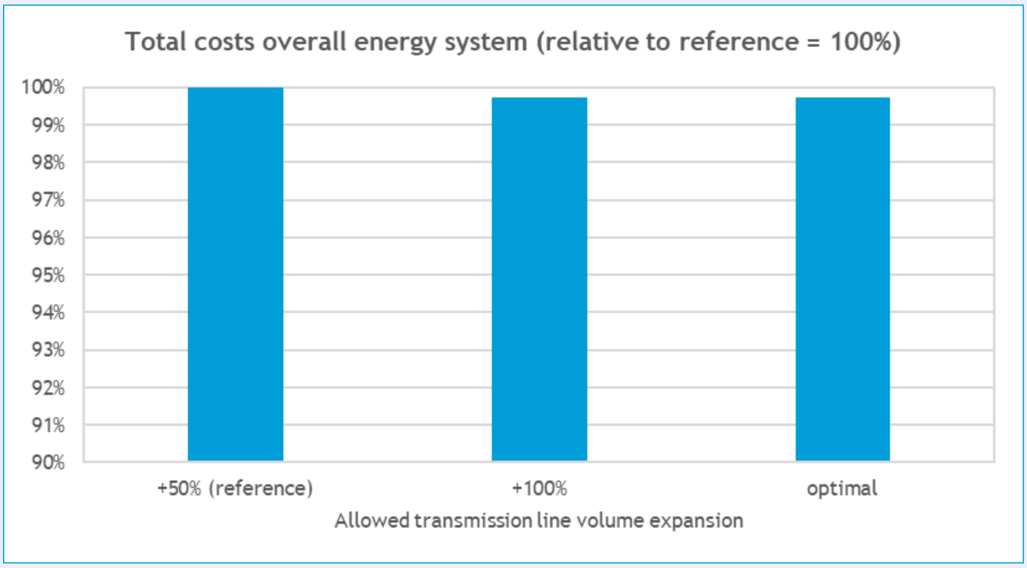
*Table 8 Overview results impact assessment of timely and efficient realisation of transnational infrastructure*

| Assessment criteria | Reference: Autonomous development transnational infrastructure | Societal optimal development transnational infrastructure |
|---|---|---|
| Overall energy cost | | Lower generation cost because of less curtailment of low-cost renewable energy and thereby lower production of more expensive gas-based generation. |
| Investment needs transnational energy-infrastructure | Less infrastructure requires less investment cost in infrastructure. | |
| Utilisation renewable energy production | | Additional transnational infrastructure increases the utilisation of renewable electricity production and thus reduces curtailment. |
| Gas-based[6] generation and back-up power | | Additional interconnectors reduce the need for gas-based generation due to higher usage of renewable production. Additional hydrogen infrastructure may reduce cost of gas-based generation and make this option more often financially viable. |
| Reduction greenhouse gas emissions | | Until the system is emission-free additional interconnectors may reduce greenhouse gas emissions due to additional renewable electricity usage and reduction of gas-based production. |
| Security of supply | | Additional interconnections can increase security of supply because of increased diversification and reduction of required balancing power. |

[6] Currently, these mainly use natural gas. In the future these powerplants use hydrogen, green gas or natural gas combined with Carbon Capture and Storage (CCS).

**Illustration with PyPSA modelling results**

The total energy system costs is somewhat lower when the transmission line volume expansion is optimal (around +100%) compared to a modest expansion of 50% (reference). The total energy system costs include both capital and operational costs of all energy transmission infrastructures (gas, hydrogen, heat and electricity) and energy generation and storage facilities (including heat generation, for example heat pumps).




Note: the y-axis starts at 90%. A few percent reduction in the yearly overall energy system costs will result in costs saving of a 1-3 billion euro a year for the European energy system as a whole.

These findings are similar with scientific studies. A study from Schlachtberger et al. (2017) analysed the effect of different levels of interconnecting transmission on the costs of the European electricity system, assuming a reduction of $CO_2$ emissions of 95% compared to 1990 levels (the EU goal for 2050). They concluded that "an expansion to four times today's interconnection capacities already enables 85% of the cost savings of the optimal transmission expansion (nine times today's)".

More infrastructure investments will only result in lower overall energy system costs as long as infrastructure investments do not exceed the optimal transmission line volume. Moreover, an overall optimal energy system is assumed in the PyPSA modelling. Optimal transmission line volume expansion will result in lower overall energy system costs if the energy system also makes optimal use of this infrastructure.

Effects outside of the scope of this study are:

- **Grid losses** have not been modelled or qualitatively assessed. Grid losses could decrease due to more constant power flows and increase in voltage levels. However, grid losses could also increase due to transport over longer distances.
- **Residual Environmental impact** characterises the (residual) project impact on the environment, as assessed through preliminary studies, and aims to provide a measure of the environmental sensitivity associated with the project. This criterion is not included in many studies regarding transnational infrastructure and could not be assessed.
- **Residual Social impact** characterises the (residual) project impact on the (local) population affected by the project, as assessed through preliminary studies, and aims to provide a measure of the social sensitivity associated with the project. This criterion is not included in many studies regarding transnational infrastructure and could not be assessed.

### 6.2.2 Overall energy cost (SEW)

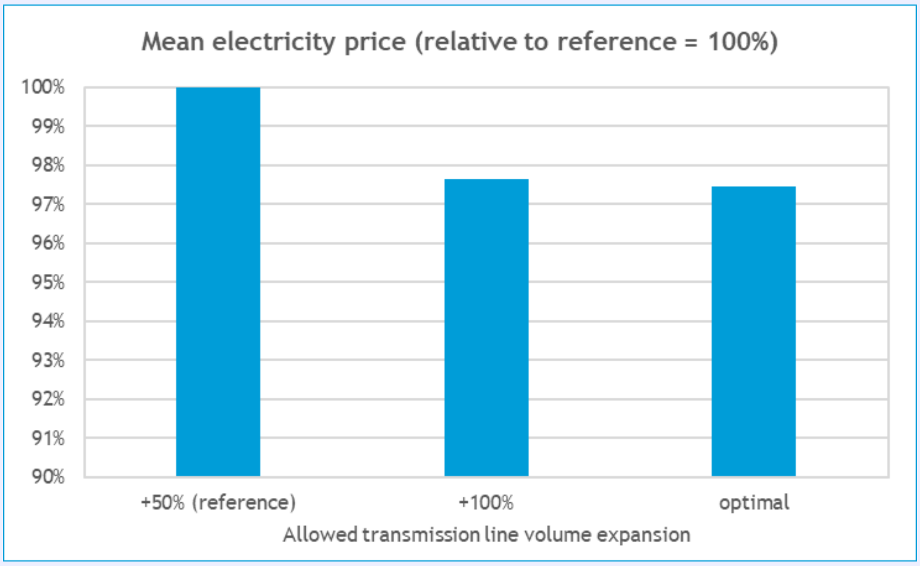
The overall electricity generation cost is often named social economic welfare (SEW) in transnational energy infrastructure studies. These cost are determined by the hourly electricity prices, which includes investment cost and operational cost for the technologies which supply the electricity (gas generators, solar, wind, storage etc.). Cost for the network infrastructure are not includeded (these follow in Section 6.2.3).

The total cost of energy production is lower in a scenario with additionaal cross-border infrastrastructure according to literature. The lower generation cost are due to less curtailment of low-cost renewable energy and thereby lower production of more expensive gas-based generation. Surpluses of renewable electricity can be transported to other countries and thereby used more efficiently. Furthermore prices are reduced since additionel competition is created between expensive gas-based generators (Maciver et al., 2021). For example, (Child et al., 2019) concluded that a system without additional investments in interconnectors would result in an average electricity price of 56 €/MWh in 2050 in Europe, while a scenario with increase in interconnector capacity results in an electricity price of approximaly 51 €/MWh.

Additional transnational hydrogen infrastructure can result in overall lower energy cost due to additional production in areas with large potential for renewable energy production, like Spain (solar PV) or the Denmark (offshore wind). With additional transnational infrastructure this hydrogen can be transported to countries with high demand and low renewable energy production potential. Thereby the overal production cost in areas with large scale production can further decrease due to economy of scale.

**Illustration with PyPSA modelling results**

Although the modelled energy system does not include conventional gas-based electricity generation, allowing for optimal transmission line volume expansion results in a 3% lower mean electricity price (marginal price).




Note: the y-axis starts at 90%.

*Table 9 Impact assessment overall electricity cost*

| Assessment criteria | Reference: Autonomous development transnational infrastructure | Societal optimal development transnational infrastructure |
|---|---|---|
| **Overall electricity cost** | | Lower generation cost because of less curtailment of low-cost renewable energy and thereby lower production of more expensive gas-based generation. |

## 6.2.3 Investment transnational energy infrastructure

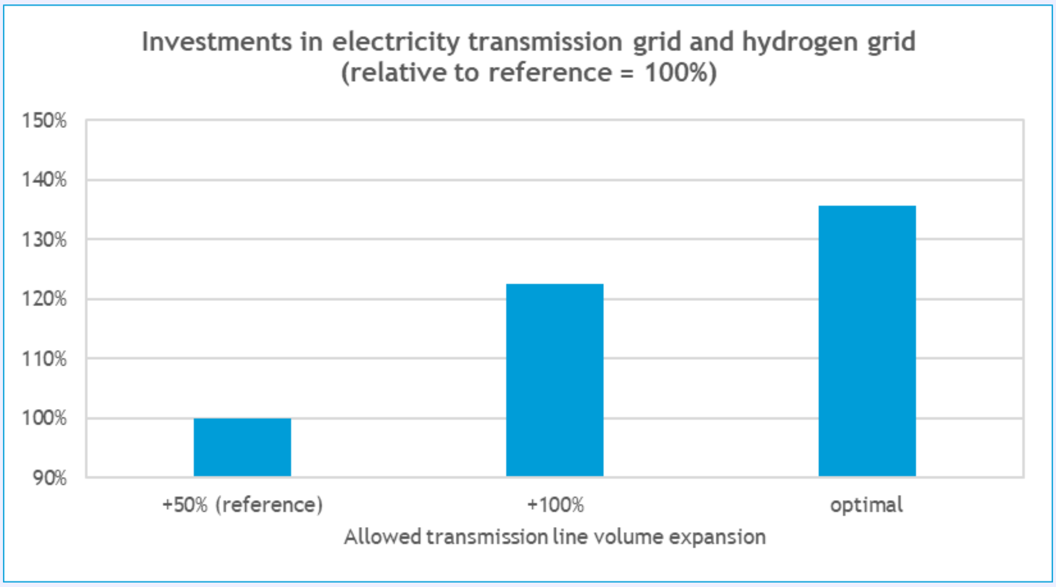
For the realisation of transnational energy infrastructure investments are required. In 2015 the ACER published reports on the transnational infrastructure cost for electricity and gas (Acer, 2015). These reports offer, slighlty outdated, insight in the reference cost for this infrastructure. For example, overhead lines have an mean investment cost from 290,000 €/km (220-225 kV, one circuit) up to 1,060,000 €/km (380-400 kV, two circuits). The mean investment cost for an onshore AC substation are estimated at 39,000 €/MVA. ENTSO-E estimates an annual investment need of approximately 6 billion euros (3,5 billion for cross-border capacity, 2 billion for storage and 0,1 billion for peaking units) for a societal optimal European transnational electricity network between 2025 en 2040 (Entso-E, 2022b).

For hydrogen infrastructure the European Commission has identified a total investment need of € 28 to 38 billion untill 2030 (European Commission, 2023a). This is for the total hydrogen infrastructure in Europe, so both national and transnational. A recent report indicates a total investment need in European hydrogen backbone towards 2040 of € 80 to 143 billion (Amber Grid et al., 2022).

On the other hand, from a system perspective the total energy system costs are expected to reduce when additional transnational (interconnection) infrastructure is realised. The total system costs include costs of storage and generation of energy, next to the tansmission infrastructure costs.

**Illustration with PyPSA modelling results**

Allowing for more transmission line volume expansion results in more grid expansion until the optimal grid expansion has been reached. As a result, the investment costs for electricity transmission grid expansion and hydrogen grid expansion (and repurpose of gas grids) will increase, as shown in the figure below.




Note: the y-axis starts at 90%.

*Table 10 Impact assessment investment transnational energy infrastructure*

| Assessment criteria | Reference: Autonomous development transnational infrastructure | Societal optimal development transnational infrastructure |
|---|---|---|
| **Investment transnational energy infrastructure** | Less infrastructure requires less investment cost in infrastructure. | |

## 6.2.4 Utilisation renewable energy production

The realisation of more transnational energy infrastructure reduces the curtailment of renewable energy production. The infrastructure enables transport of surpluses of renewable energy production to other countries, thereby increasing the utilisation of renewable energy production in the EU. The ENTSO-E found that increasing the transnational network could increase renewable energy utilisation in the EU with 17 TWh in 2030 and 42 TWh in 2040 (Entso-E, 2022a).

**Illustration with PyPSA modelling results**

Allowing for more transmission line volume expansion in the model results overall in lower curtailment of renewables. This effect is illustrated in the figure below for the curtailment of wind turbines. Curtailment is reduced at optimal transmission line volume expansion (around +100%) compared to a modest expansion of 50% (reference), i.e. more of the generated electricity from wind turbines could be uses effectively.

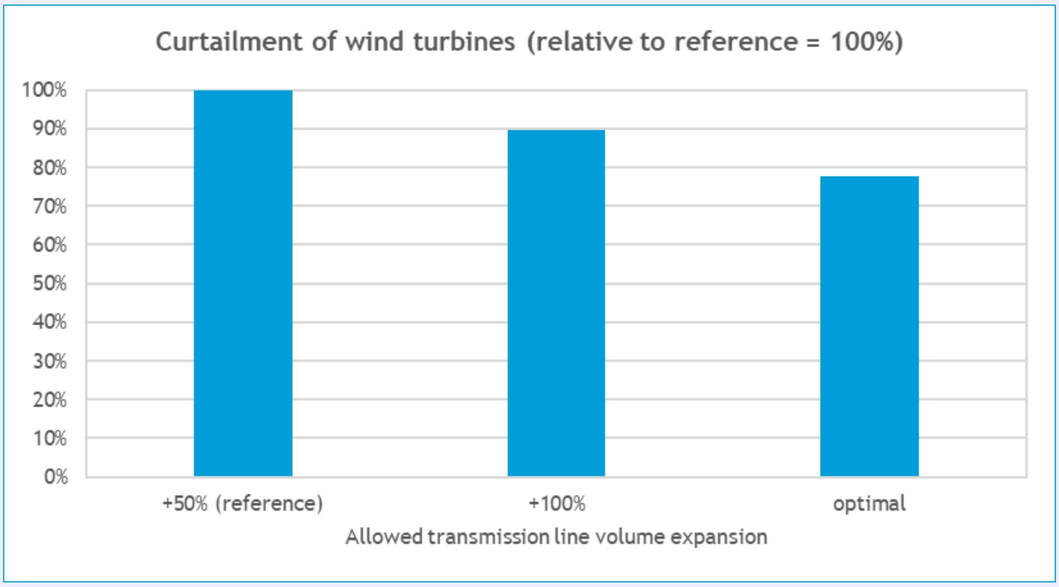



*Table 11 Impact assessment utilisation renewable energy production*

| Assessment criteria | Reference: Autonomous development transnational infrastructure | Societal optimal development transnational infrastructure |
|---|---|---|
| **Utilisation renewable energy production** | | Additional transnational infrastructure increases the utilisation of renewable electricity production and thus reduces curtailment. |

### 6.2.5 Gas-based generation and back-up power

Additional transnational electricity infrastructure may have two effects on gas-based powerplants[7]:

1. Reduced electricity generation from these gas-based power plants (GWh). This will affect overall energy cost and potentially lead to reduction of $CO_2$ emissions.
2. Reduced required capacity of gas-based plants (GW). This will reduce energy and investment cost.

In the ENTSO-E analysis of additional transnational infrastructure it was found that an optimal selection of transnational energy infrastructure leads to a reduction of electricity generation by gas-based power plants of 9 TWh/year in 2030 and 75 TWh/year in 2040 (Entso-E, 2022a).

The realization of additional hydrogen infrastructure can also effect the gas-based generation in Europe. It can result in a better position for gas-based generation since it increases it security of supply and may reduce hydrogen prices. Therefore hydrogen-based generation may be a more financially viable source of flexibility and therefore increase.

*Table 12 Impact assessment gas-based generation and back-up power*

| Assessment criteria | Reference: Autonomous development transnational infrastructure | Societal optimal development transnational infrastructure |
|---|---|---|
| **Gas-based generation and back-up power** | | Additional interconnectors reduce the need for gas-based generation due to higher usage of renewable production. Additional hydrogen infrastructure may reduce cost of gas-based generation and make this option more often financially viable. |

[7] Currently, these mainly use natural gas. In the future these powerplants use hydrogen, green gas or natural gas combined with Carbon Capture and Storage (CCS).

### 6.2.6 Reduction greenhouse gas emissions

In this analyses we have modelled the effect of transnational infrastructure in 2050. The analysis is based on the assumption that the energy system is completely climate neutral and solely based on renewable energy sources in 2050. Therefore, the amount of greenhouse gas emissions does not differ between the scenarios with different amounts of transnational energy infrastructure. In the period towards 2050, when the energy systems is not climate neutral yet, additional transnational infrastructure will results in reduction of greenhouse gas emissions, since additional transnational infrastructure results in less electricity production with gas-based power plants and less curtailmentof renewable energy production (see Sections 6.2.4 and 6.2.5). ENTSO-E concludes that the realization of additional transnational infrastructure could reduce tje yearly greenhouse gas emissions with 31 Mton in 2040 in Europe (Entso-E, 2022a).

*Table 13 Impact assessment reduction greenhouse gas emissions*

| Assessment criteria | Reference: Autonomous development transnational infrastructure | Societal optimal development transnational infrastructure |
|---|---|---|
| **Reduction greenhouse gas emissions** | | Until the system is emission-free additional interconnectors may reduce greenhouse gas emissions due to additional renewable electricity usage and reduction of gas-based production. |

### 6.2.7 Security of supply

Security of supply comprises the reliability of the energysystem to supply the required energy at any given moment. Security of supply has two main factors which differ in the timescale:

1. **Short-term energy balancing**: electricity balancing is required to match supply and demand of electricity on the time scale of seconds and minutes. This type of energy balancing will be supplied by fast-responsive energy storage such as batteries, demand response and flexible generation capacity.
2. **Long-term energy balancing (adequacy)**: Energy balance on weekly or seasonal-time scale. This type of energy balancing will be supplied by large scale gas-based generation and long-term energy storage.

Additional infrastructure for electricity and hydrogen can affect the secturiy of supply in several ways. We identify two main effects:

1. **Diversification/stability**: The amount of different sources of energy supply. Additional investments in interconnections and further integration of the European energy system will enable electricity generators to support other areas or bidding zones in their demand for energy balancing or if disruptions occur. Transnational hydrogen infrastructure can

increase the security of supply of hydrogen since more sources are connected to the EU-wide hydrogen infrastructure and the dependence on single hydrogen sources decreases.

2. **Reduction of required balancing power**: The overall required gas-based generation capacity for energy balancing could be reduced with additional investments in transnational energy infrastructure (see Section 6.2.5).

In general the security of supply increases with additional transnational infrastructure. The main reasons is that an increased amount of sources can be used to supply flexibility for energy balancing in general and if any disruptions occur and the dependence on one or a few energy sources decreases.

ENTSO-E has studied the effect of additional interconnectors on the security of supply of electricity. The study concludes that the realization of additional transnational infrastructure could reduce the electricity-not-served[8] in Europe with 1,6 TWh in 2040 (Entso-E, 2022a).

*Table 14 Impact assessment security of supply*

| Assessment criteria | Reference: Autonomous development transnational infrastructure | Societal optimal development transnational infrastructure |
|---|---|---|
| **Security of supply** | | Additional interconnections can increase security of supply because of increased diversification and reduction of required balancing power |

## 6.3 Assessment impact of policy instrument on timely and efficient realisation of transnational energy infrastructure

This section contains the assessment of the policy options on timely and efficient realisation of transnational energy infrastructure. Firstly, an overview of the results of the impact assessment for all assessment criteria is given. After this, the impact assessment of each individual assessment criterium is discussed.

### 6.3.1 Overall results impact assessment

The overall results of the impact assessment are displayed in Table 15. The table shows that each of the three policy option has its benefits and drawbacks. The main distinctive aspects of the policy instruments are their impact on ensuring efficient realisation of transnational energy

8 If the security of supply is insufficient, it is possible that electricity can not be supplied. This means households and consumers can not use electricity for a certain amount of time.

infrastructure from pan-European perspective, their transformative impact, the barriers for implementation and their impact on risks for negative social and distributional effects. The consideration of the benefits and drawbacks of the policy options is political.

An elaborate overview of the impact assessment for the individual criteria is given in Sections 6.3.2 to 6.3.8.

*Table 15 Overview results impact assessment of policy options on timely and efficient realisation of transnational infrastructure*

| Assessment criteria | Policy option 1: Fragmented governance | Policy option 2: Pan-European governance | Policy option 3: Middle-of-the-road |
|---|---|---|---|
| Ensuring optimal selection of interconnections, from pan-European perspective | No guarantee that pan-European perspective will prevail above national interests | ISO with complete mandate will guarantee realisation of optimal selection of interconnections | Binding requirements by ENTSOs for TSOs will guarantee realisation of optimal selection of interconnections |
| Speed of realisation (once policy option is implemented) | Fragmented planning by large number of TSOs. But faster realisation because of better knowledge local situation. | Integrated planning for whole EU by ISO. But more complex realisation because of limited knowledge local situation. | Two steps in planning process, so more complex. But faster realisation because of better knowledge local situation. |
| Transformative impact | Fragmented planning process and not reasoned from desired end state for EU | Centralised planning and realisation by ISO, which can reason from desired end state for EU | Desired end state for EU translates into obligations for Member States, but risk of fragmented planning and realisation |
| Barriers for implementation | Close to current situation, relatively easy to implement | Requires significant changes in legislation, which requires political will, implementation time and transfer of knowledge | Same barriers as policy option 2, but to lesser extent because fewer changes in legislation are necessary |
| Interaction other policy instruments | For each of the policy options, the interaction with other policy instruments may occur in different manners and on different governance levels. However, in this study we cannot draw conclusion on whether the different policy options interact better or worse with other policy instruments. | | |
| Social and distributional aspects | Realisation by regional or national TSO with less (physical and cultural) distance to the local population. So less risk of negative social and distributional effects | Risk of poor interaction with local stakeholders, poor balance of costs and benefits and risks of local opposition because of large distance of ISO to local population. Would need to be counteracted explicitly. | Realisation by regional or national TSO with less (physical and cultural) distance to the local population. Accordingly less risk of negative social and distributional effects |

| Assessment criteria | Policy option 1: Fragmented governance | Policy option 2: Pan-European governance | Policy option 3: Middle-of-the-road |
| --- | --- | --- | --- |
| Competitiveness and employment | More interconnections lead to lower electricity prices and convergence of prices across EU, which increase competitiveness of EU.<br><br>No substantial differences for employment. Most of the employment is related to the realisation of the transnational energy infrastructure and it is expected that the realisation of the interconnections will be performed by local contractors in all three policy options | | |

### 6.3.2 How does the policy instrument ensure realisation of an optimal selection of cross-border energy infrastructure, from a pan-European perspective?

The goal of the policy instrument is ensuring that a socio-economically cost-efficient selection of cross-border energy infrastructure is realised. In absence of sufficient interconnection each country needs to build a large enough capacity of generation, as well as a large back-up capacity for storage and conversion. This overcapacity is necessary to be able to guarantee supply even in long periods of low renewable generation and high demand, such as dark windless periods in winter in Central. Interconnection allows to decrease the overcapacity needed as it enables energy flows across Europe. Periods with low renewable generation, technical unavailability, maintenance, etc. in certain regions can be accommodated by making use of facilities in different regions in Europe.

The socio-economically cost-efficient selection of cross-border interconnection can be determined in terms of cost-optimisation of installed capacity (including flexibility technologies) and interconnection. Thus, the policy instrument needs to make sure that an efficient selection of cross-border energy infrastructure is realised by considering an integrated cost-benefit analysis that includes transmission (cables and pipes), generation, and flexible and conversion capacity infrastructure for the EU as a whole.

With policy option 1, Fragmented governance, decisions for cross-border energy infrastructure investments are made on Member State level by individual TSOs. The ENTSOs make pan-European assessments of investments necessary for an efficient energy system. Projects increasing the efficiency of the energy system can receive benefits by obtaining PCI-status. However, there is no guarantee that the efficient selection of cross-border interconnections will be realised, since the decisions are made by individual TSOs and Member States, primarily acting in their own national interests. If national interests conflict with pan-European interests, interconnections are likely not realised in the most efficient way.

**Example conflict pan-European interests with national interests**

If national interests conflict with pan-European interests, interconnections are likely not realised in the most efficient way with policy option 1. This may happen in the following hypothetical example.

The Iberian peninsula (Spain and Portugal) has a large potential for cheap renewable energy production and consequentially for cheap green hydrogen production. In Central Europe, the potential for cheap green hydrogen production is limited. Therefore, from a pan-European view, it may be efficient to realise a transnational hydrogen pipeline from the Iberian peninsula to Central Europe. This hydrogen pipeline has to cross France. However, France may have its own aspirations for (more expensive) hydrogen production and export with its nuclear power plants and these aspirations may be negatively affected by the transnational hydrogen pipeline from the Iberian peninsula to Central Europe.

Therefore, this may lead a conflict between pan-European interests with national interests which may cause that this transnational hydrogen pipeline will not be realised with policy option 1.

With policy option 2 (fully centralised European-level governance) and policy option 3 (Centralised European incentives with decentralised Member-State-level decision-making) pan-European organisations have the mandate to determine how much interconnections will be realised. Therefore, an efficient selection of cross-border interconnections can be determined on EU-level. EU-level responsible parties in these two policy options have both the mandate and the tools to ensure that these interconnections are realised in the entire EU. Therefore, policy options 2 and 3 are more likely to ensure an efficient selection of cross-border energy infrastructure across all of the EU. With policy option 1, it is possible that an efficient selection of cross-border energy infrastructure is realised in the EU but there is no guarantee that the current processes lead to an optimal system from a pan-European system since national interests may prevail.

*Table 16 Impact assessment optimal selection interconnections*

| Assessment criteria | Policy option 1: Fragmented governance | Policy option 2: Pan-European governance | Policy option 3: Middle-of-the-road |
|---|---|---|---|
| **Ensuring optimal selection of interconnections, from pan-European perspective** | No guarantee that pan-European perspective will prevail above national interests | ISO with complete mandate will guarantee realisation of optimal selection of interconnections | Binding requirements by ENTSOs for TSOs will guarantee realisation of optimal selection of interconnections |

### 6.3.3 How does the policy instrument affect the speed of the roll-out of the required energy infrastructure (once the policy instrument is realised)?

As this policy instrument has planning at its heart, it can support timely realisation of project. Planning is necessary to realise projects in a timely manner. Lack of planning or long planning procedures increase the risk of delays. Transnational energy infrastructure projects have often faced delays in the past. Going forward, such delays would negatively impact $CO_2$ emission reductions and costs of electricity (Ritter et al., 2019), and should therefore be avoided.

As transnational infrastructure projects are typically large projects involving many stakeholders, planning is a key feature of this instrument to avoid delays. Planning makes sure long lead times for infrastructure construction can be foreseen and addressed timely. Components of the policy instrument that are key to timely realisation are coordination of scenarios and infrastructure planning procedures, use of procedures that have been streamlined and coordinated across the countries involved (ideally, the entire EU), and timely involvement of local stakeholders and adoption of finetuned participation processes to avoid lengthy opposition.

For this criterion, we only consider the effects of the policy instruments on timely realisation of energy infrastructure *once the policy instrument is implemented.* The time necessary to implement the different policy options will not be taken into account in this criterion, this will be considered in Section 6.3.5.

With policy option 1, cross-border interconnections are realised by national or regional TSOs. These TSOs operate within the countries between which the interconnections are realised and therefore have good insight in national procedures, permitting and local stakeholder interests. They moreover have closer links to local governments than EU-level entities. It is expected that this local proximity contributes to faster realisation of individual interconnections. However, with policy option 1, the investments in necessary interconnections are realised separately by a large number of national TSOs. This may affect the speed of the planning of cross-border energy infrastructure compared to a policy option in which decisions for all interconnections are made by a single entity at European level.

With policy option 2, one single EU-entity with much clout is responsible for the planning and investments in cross-border interconnections across all of the EU. Therefore, decisions which investments in pan-European energy infrastructure are necessary can be made more swiftly compared to the situation in which these decisions have to be made by several dozens separate TSOs. However, bringing the authority to the EU-level may affect the speed of the actual realisation of the interconnections because there is more distance between the competent authority and the local stakeholders and governments. Furthermore, an EU-entity is expected to have less knowledge about local procedures and permitting, thus delaying the progress of realising interconnections. Extensive coordination between the ISO and local stakeholders is necessary to make sure the realisation of transnational energy infrastructure happens swiftly.

With policy option 3, the planning process consists of two steps. First, on the EU-level, the assessment is made of the necessary cross-border interconnections, which are then translated into obligations for investments for national and regional TSOs. After this, these TSOs have to implement these obligations through concrete project plans. This double step in the planning process affects the speed of the planning. However, since the projects are realised by national and regional TSOs, they can use the insights on local procedures, local stakeholders interests, and permitting for faster and more efficient realisation of the cross-border interconnections than an EU-level entity.

Concluding, each of the policy options has aspects which may lead to faster realisation of transnational energy infrastructure and other aspects may lead to risks of delay. Therefore, all policy options score neutral for this criterion.

*Table 17 Impact assessment speed of realisation*

| Assessment criteria | Policy option 1: Fragmented governance | Policy option 2: Pan-European governance | Policy option 3: Middle-of-the-road |
|---|---|---|---|
| **Speed of realisation (once policy option is implemented)** | Fragmented planning by large number of TSOs. But faster realisation because of better knowledge local situation. | Integrated planning for whole EU by ISO. But more complex realisation because of limited knowledge local situation. | Two steps in planning process, so more complex. But faster realisation because of better knowledge local situation. |

### 6.3.4 To which extent is this core instrument expected to deliver a transformative impact towards neutrality in the EU?

The way in which the planning of new infrastructure is performed, can be either based on incremental changes compared to current practices or can be based on systemic changes. When reasoned from the desired end state in an holistic approach, systemic changes are more likely and policies will become more transformative (Görlach et al., 2022). Therefore, policy instruments are called transformative when the decisions are made reasoned from a desired end state of a climate neutral European energy system with an efficient selection of transnational energy infrastructure, from a pan-European perspective.

With policy option 1, the process of planning cross-border interconnections essentially remains the same to the current process. The current planning process is established in times with relatively small changes to the energy system with incremental expansion of the cross-border interconnections. Decisions are made based on national interest and the European energy system as a whole will only to a limited extent be taken as a perspective. Furthermore, investments in these interconnections are made separately by a large number of TSOs. This means that the decision making process is fragmented and will likely lead to incremental changes instead of decisions reasoned from a desired end state. Therefore, policy option 1 is not expected to deliver a transformative impact.

With policy option 2, a single pan-European entity, the ISO, has the mandate for the roll-out of the necessary cross-border interconnections. The establishment of the ISO is a structural and systemic change in the field of energy infrastructure. Power is moved away from Member States towards the European Union and concentrated at a single entity. The ISO can make the decisions based on the desired end state of a climate neutral EU and with a pan-European view. In this way, path dependencies can be overcome. Therefore, this policy option can deliver a transformative impact.

With policy option 3, a single pan-European authority formulates mandatory conditions for transnational infrastructure, to which Member States and their TSOs are required to adhere. Since a pan-European authority makes decisions about the interconnections and has the mandate to enforce it, this policy instrument can also deliver a transformative impact towards a systemic change. However, final investment decisions will still be made on national level (by many different TSOs), which means these decisions will still be influenced by national interested to the extent this will be possible within the boundary conditions set on EU level and that the decision making process is fragmented. Therefore, this policy option deliver less of a transformative impact than policy option 2. But this policy option is more likely to deliver a transformative impact compared to the current situation because of the mandatory conditions set by a single pan-European entity.

*Table 18 Impact assessment transformative impact*

| Assessment criteria | Policy option 1: Fragmented governance | Policy option 2: Pan-European governance | Policy option 3: Middle-of-the-road |
|---|---|---|---|
| **Transformative impact** | Fragmented planning process and not reasoned from desired end state for EU | Centralised planning and realisation by ISO, which can reason from desired end state for EU | Desired end state for EU translates into obligations for Member States, but fragmented planning and realisation |

## 6.3.5 What are the barriers for implementation of the policy instrument?

There are several barriers for implementation, which depend on the specifics of the instrument. The most important barriers for implementation of the policy options are:

- **Political will.** The most important barrier is the political will to implement certain policy options. Energy policy has historically fallen within national jurisdiction. Current procedures, as well as the lay-out of infrastructure reflect this. Long-term plans are made based on individual countries self-interest. Moreover, there has been a historical focus on self-sufficiency within a country. This historical national viewpoint on energy infrastructure is an important barrier for implementing a European-oriented instrument. This applies specifically for policy option 2, since all competence for cross-border energy infrastructure will be transferred towards EU authorities. With policy option 3, a large share of the powers will be transferred to EU authorities, who then can formulate and enforce mandatory conditions for Member States. However, Member States and TSOs remain responsible for the realisation of the cross-border energy infrastructure. With policy option 1, the competence remains on Member-State-level. This being a 'business-as-usual' scenario, it is more inclined to be in line with political will and this barrier does not apply to this option.

- **Implementation time.** Another barrier is the implementation time of the policy instrument. When substantial changes have to be made in legislation and the planning process, this takes time. The most important aspects which affect the implementation time are:

  - ***Changes in legislation.*** For policy option 2, substantial changes in the TEN-E Regulation, the Electricity Directive and possibly other Directives are necessary to form new organisations and strengthen existing ones. The specific characteristics of the policy instrument have to be sorted out, for example regarding the distribution of costs. Implementing these changes will take time, especially because of the political sensitivity of the changes (see previous point). Policy option 3 aligns more with the current legislation, so less changes are necessary. However, the existing organisations (ENTSOs and ACER) also have to gain more power in this policy option and some changes in legislation are necessary. Policy option 1 aligns with the current legislation and competences, so few changes are necessary.

  - ***New organisations.*** With policy option 2, a new organisation, the Interconnection System Operator (ISO), will be formed out of the existing ENTSOs and ACER needs to be strengthened and gain more competence. Doing so takes time. The ISO has to realise a proper organisation structure. Qualified employees have to be found and they have to find a way of operating. The same applies to ACER, which will gain a formal role as regulator for the cross-border energy infrastructure in this policy option. Furthermore, a proper governance structure between the ISO, ACER, national/regional TSOs and governments has to be shaped. With policy option 3, the realisation of interconnections remains the responsibility of national/regional TSOs, so the changes are less disruptive. However, with this policy option the ENTSOs and ACER still have to be strengthened. With policy option 1, no fundamental changes within the organisations are necessary.

  - ***Financing.*** For policy option 2, the newly formed ISO needs to have substantial amounts of funding to be able to invest in transnational energy infrastructure. These investments can be financed in different ways. Furthermore, ACER needs to receive additional funding to be able to perform their additional tasks. Agreeing on the proper financing schemes and arranging these schemes takes time. With policy option 3, the ENTSOs and ACER are strengthened and need additional funding. However, with this policy option the actual investments are still made by TSOs. Therefore, less changes in financing are necessary. With policy option 1, no fundamental changes in financing are necessary.

- **Transfer of knowledge.** Knowledge of the existing energy infrastructure and other relevant aspects in Member States, like local procedures, stakeholders interests and permitting, is crucial for realisation of cross-border energy infrastructure. Currently, mainly national/regional TSOs and to a lesser extent national regulators possess this knowledge. With policy options 2 and 3, this knowledge has to be transferred properly to the EU-level and extensive coordination between the competent authorities on EU level and local parties is necessary. Sharing of data and information is a practical barrier for implementation. It is important that this knowledge is transferred adequately from the TSOs and national regulators to either the ISO (policy option 2) or the ENTSOs (policy option 3), as well as to ACER (both policy option 2 and 3). Otherwise, asymmetrical knowledge between regulators and transmission system operators may occur which may lead to suboptimal control by ACER.

Concluding, many changes are necessary for policy option 2 which will lead to some substantial barriers for implementation of the instrument. With policy option 3, less changes are necessary and less barriers need to be overcome for implementation of the policy instrument. Policy Instrument 1 is close to the existing situation, so implementation of this instrument faces little barriers.

*Table 19 Impact assessment barriers for implementation*

| Assessment criteria | Policy option 1: Fragmented governance | Policy option 2: Pan-European governance | Policy option 3: Middle-of-the-road |
|---|---|---|---|
| **Barriers for implementation** | Close to current situation, relatively easy to implement | Requires significant changes in legislation, which requires political will, implementation time and transfer of knowledge | Same barriers as policy option 2, but to lesser extent because fewer changes in legislation are necessary |

### 6.3.6 How does the policy instrument interact with other policy instruments and how may this affect the effectivity?

The development of transnational transmission capacity should be synchronised with instruments supporting the development of renewable generation capacity, those supporting flexible operator's capacities, and those supporting the demand-side transition to electricity or hydrogen and away from fossil fuels and feedstocks. In particular, these instruments include cross-sector planning instruments, and financing and support schemes that increase incentives and decrease uncertainties. Furthermore, interaction with other policy areas, especially spatial planning is, important.

Furthermore, energy infrastructure planning interacts with market design. Past experiences show that no planning or poor interaction results in undesirable electricity flows, such as experienced in Central Europe following the Energiewende in Germany, while Germany, Austria and Luxembourg were one bidding zone. Lack of transmission within Germany resulted in unwanted electricity flows in neighbouring countries such as the Czech Republic and Poland (Janda et al., 2017). Since, the German-Austrian bidding zone has been split up and efforts are taken to create more bidding zones in Germany (Acer, 2022). Thus, transnational infrastructure, market design (e.g., bidding zones), and expansion of renewable energy resources, flexibility technologies' capacities and demand-side energy carrier use should all be developed in an integrated fashion. This applies to all three policy options. For each of the policy options, the interaction with other policy instruments may occur in different manners or on different governance levels.

Policy option 1 is closely related to the current situation, which means that the interaction with other policy instruments is already arranged in current legislation. With policy options 2 and 3, the interaction with other policy instruments requires additional efforts and changes in legislation in related policy areas. However, this also creates the opportunity to improve the interaction between transnational energy infrastructure planning policy and other policy areas.

Another relevant aspect for the interaction with other policy instruments is the fragmentation of the planning process with policy option 1 and, to a lesser extent, policy option 3. With these policy options, the investment decisions for transnational energy infrastructure are made on Member State level by dozens of different TSOs. Therefore, proper interaction with national policy instruments is necessary in each of the Member States, on top of proper interaction with EU policy instruments. With policy option 2, the invest decisions for transnational energy infrastructure are made on EU level. For proper interaction with other policy instruments, the mandate for decisions regarding market design (e.g., bidding zones) and expansion of renewable energy resources, flexibility technologies' capacities and the demand-side transition should also be transferred to EU level. In this way, all decisions regarding the development of the European energy system can be made in an integrated fashion at EU level.

Concluding, the policy instrument Integrated Infrastructure Planning mainly interacts with policy instruments regarding market design (e.g., bidding zones) and expansion of renewable energy resources, flexibility technologies' capacities and the demand-side transition. Furthermore, interaction with other policy areas, like spatial planning, is crucial. For each of the policy options, the interaction with other policy instruments may occur in different manners or on different governance levels. However, it cannot be concluded whether the different policy options interact better or worse with other policy instruments.

*Table 20 Impact assessment interaction with other policy instruments*

| Assessment criteria | Policy option 1: Fragmented governance | Policy option 2: Pan-European governance | Policy option 3: Middle-of-the-road |
|---|---|---|---|
| **Interaction other policy instruments** | For each of the policy options, the interaction with other policy instruments may occur in different manners and on different governance levels. However, in this study we cannot draw conclusion on whether the different policy options interact better or worse with other policy instruments. | | |

### 6.3.7 What is the impact on health, the socio-technical transition processes and social and distributional aspects, including the gender dimension?

Integrated infrastructure planning is part of the larger socio-technical transition process towards a sustainable energy system. Its implementation should therefore consider the impact on the socio-technical processes, including health, social and distributional aspects. The gender dimension with respect to infrastructure is generally addressed in literature for developing countries, where access to electricity is considered to be an empowering factor for women, e.g., (Energy Sector Management Assistance Program, 2018), (Osunmuyiwa & Ahlborg, 2019). To address the gender dimension of the impact of cross-border electricity infrastructure in Europe, dedicated research is necessary. Meanwhile, local stakeholder processes in decision-making should be designed in such a way to be inclusive, and support gender equal participation. This applies to all policy options. There is no clear differentiation between the three policy options.

When applying the integrated infrastructure planning instrument, careful attention should be paid to the interaction between planners on the one hand and local stakeholders affected by the infrastructure on the other hand. New infrastructure often benefits the larger community, while local residents bear the largest burden (in terms of monetary or non-monetary costs). Lack of understanding of planners of the local concerns can thwart the realisation of the cross-border infrastructure (Cohen et al., 2014).

Infrastructure projects often face local opposition due to aspects that decrease welfare, or are perceived as such, for instance decreased landscape quality, safety concerns, decreased property values, procedural injustice, etc. Such aspects can be balanced by those that increase welfare, or are perceived as such, for instance, economic development, energy security, compensation, procedural justice, etc. Local stakeholders therefore should be compensated for loss in welfare. (Cohen et al., 2014).

Cost-benefit analyses for each transnational interconnection should be carried out, and should include potential loss in local health and wealth. Procedures for planning new transnational lines should involve the public early, should not be based on pre-made assumptions about the public sentiment ("always ask, never assume"-principle), should carefully consider siting with respect to the local landscape and local values for it, and should address potential health concerns of local residents.

With policy option 1 and policy option 3, regional or national TSOs are responsible for the realisation of cross-border energy infrastructure. Therefore, competent authorities have less (physical and cultural) distance to the local population compared to policy option 2, at which a European ISO is responsible for the realisation of these interconnections. Therefore, the risk of poor interaction with the local stakeholders and consequentially poor balance of incomes and expenses and local opposition is much larger with policy option 2.

*Table 21 Impact assessment social and distributional aspects*

| Assessment criteria | Policy option 1: Fragmented governance | Policy option 2: Pan-European governance | Policy option 3: Middle-of-the-road |
|---|---|---|---|
| **Social and distributional aspects** | Realisation by regional or national TSO with less (physical and cultural) distance to the local population. So less risk of negative social and distributional effects | Risk of poor interaction with local stakeholders, poor balance of costs and benefits and risks of local opposition because of large distance of ISO to local population. Would need to be counteracted explicitly. | Realisation by regional or national TSO with less (physical and cultural) distance to the local population. Accordingly less risk of negative social and distributional effects |

## 6.3.8 What is the impact on competitiveness and employment?

Interconnections enable the integration of different (regional) energy markets, thus increasing competition and resulting in better prices for energy consumers (Commission Expert Group, 2017). Transnational energy infrastructure improves competitiveness, as more integration leads to convergence of prices from different bidding zones in the EU and consequentially to more stable energy wholesale price across the entire EU. The convergence of energy prices is hinged on the ability to transport energy without bottlenecks throughout the entire EU, i.e., on sufficient transnational transport capacity.

More transnational energy infrastructure also improves the utilisation of renewable generation. Connected countries can make better use of the complementarities in renewable generation patterns and different generation and demand mixes. This leads to lower electricity prices within the Member States and thus improves competitiveness. How the transnational energy infrastructure is realised (with which policy option) is not relevant for the energy prices, so there is no differentiation between the three policy options on this point. Some other factors related to competitiveness may differ between the three policy options, but is expected that the effects on the energy prices are the most relevant for the competitiveness of the EU.

Investments in transnational energy infrastructure has a positive impact on employment within the Member States. Labour power is necessary for planning (by TSOs) and realisation (by contractors). With policy option 2, in which the European ISO is responsible for the realisation of these interconnections, the planning process is performed on the EU-level instead of Member-State-level. However, most of the employment is related to the realisation of the transnational energy infrastructure and not to the planning. And it is expected that the realisation of the interconnections will be performed by local contractors and thus remain on member state level. Furthermore, national or regional TSOs will only have to give up the competences for transnational energy infrastructure, which is a small fraction of their total activities. Therefore the expected negative impact of policy option 2 on local employment, compared to the other policy options, is marginal.

*Table 22 Impact assessment competitiveness and employment*

| Assessment criteria | Policy option 1: Fragmented governance | Policy option 2: Pan-European governance | Policy option 3: Middle-of-the-road |
|---|---|---|---|
| **Competitiveness and employment** | More interconnections lead to lower electricity prices and convergence of prices across EU, which increase competitiveness of EU.<br><br>No substantial differences for employment. Most of the employment is related to the realisation of the transnational energy infrastructure and it is expected that the realisation of the interconnections will be performed by local contractors in all three policy options. | | |

# 7. Conclusions and policy recommendations

## 7.1 Conclusions

Given the long lead times, timely roll-out of this energy infrastructure is crucial. This applies to both infrastructure investments within Member States as investments in transnational energy infrastructure between Member States. In this case study the core instrument *Integrated infrastructure Planning* has been assessed. The focus is on transnational infrastructure within the EU, i.e., on energy infrastructure between countries. We further primarily consider electricity and hydrogen infrastructure since these energy carriers are expected to be the key ones in a climate neutral energy system.

### 7.1.1 Developments energy system

The Climate Law, legally binding for the European Union as a whole, mandates the EU to be climate neutral by 2050. To achieve this objective, all sectors will have to undergo considerable transformation. The energy sector, and energy infrastructure as part thereof, is the enabler for other sectors to achieve climate neutrality.

The energy system is 2050 will be very different from the energy system now. The system changes can be summarised in five intertwined trends with each its own implications for the energy system:

1. Lower overall energy demand.
2. Large share renewable energy production.
3. Changing roles of energy carriers.
4. Strong system integration.
5. Fewer energy imports from outside the EU.

Because of these system changes, the need for transnational energy infrastructure increases. How much transnational energy infrastructure is necessary depends on how the developments to a climate neutral energy system takes form and on choices regarding import of energy, use of energy carriers and development of renewable energy sources. But in all scenarios of a climate neutral energy system in the EU, more interconnection between countries is desirable. This applies to both the European electricity infrastructure, which already contains significant interconnections between countries and the hydrogen infrastructure, which still has to be developed. For electricity infrastructure, it is expected that more than double the amount of interconnection capacity is desirable towards 2050 to make optimal use of the renewable energy sources within the EU and minimise the total energy system costs (Entso-E, 2022b). For hydrogen, a pan-European backbone may be feasible. Current natural gas infrastructure can be repurposed and used to transport hydrogen in the future. A pan-European hydrogen network would enable the connection of regions with large potential for hydrogen supply with regions with large hydrogen demand (and limited potential for supply) by large transport corridors (Amber Grid et al., 2022).

The aforementioned expansions of transnational energy infrastructure requires investments, but it leads to significant benefits which outweigh the costs, which means that transnational energy infrastructure leads to lower total costs for the energy system. The main benefits of transnational energy infrastructure investments are:

- higher utilisation of renewable energy production and less curtailment because of usage via interconnectors;
- less back-up power necessary due to additional renewable energy utilisation;
- reduction of greenhouse gas emissions toward 2050 because of higher utilisation renewable energy;
- increased security of supply because of increased access to energy sources within the EU;
- lower overall energy costs and total energy system costs because of higher utilisation renewable energy sources and less high-cost production units.

Underinvestment or overinvestments in transnational energy infrastructure may lead to higher costs for the energy system and may delay the transition towards a climate neutral energy system in the EU. This emphasises the necessity of proper planning of transnational energy infrastructure.

### 7.1.2 Current policies and gaps

Considering the hardware of the transnational infrastructure, at European level there are several relevant policy documents. The Third Energy Package (2009) already included regulation on improving cross-border network access by creating the ENTSO (gas/electricity) entities and demanding them to develop a community-wide network development plan every two years, the so-called Ten-Year Network Development Plan (TYNDP), including scenario development. This was the first step in EU-wide policies concerning the planning of infrastructure.

In 2013, the TEN-E Regulation (Trans-European Network for Energy) was published, aiming to accelerate the development of strategically important infrastructure projects along priority corridors. This regulation describes the process of the selection, implementation and monitoring of so-called PCIs (Projects of Common Interest). The PCIs are individual cross-border infrastructure projects that seem essential for one of the different priority corridors, and therefore will receive (financial) support and other benefits. The Ten-E Regulation describes the selection of the PCIs, which should be done following different criteria, amongst which a cost-benefit analysis.

The TYNDPs of the ENTSOs plans contain the needs in terms of energy infrastructure for the next ten years for the entire EU, based on different scenarios and modelling results and taking into account the European climate policy objectives. However, the TYNDPs are not binding in any way: the national TSOs are solely deciding on infrastructure investments, and are free to make use of the suggestions included in the TYNDP for their investment planning, or to disregard them. In reality, the assessment by the TSOs of what is needed in terms of new or enhanced connections will often coincide with the TYNDPs results, if only because the TSOs are involved in the process leading to the TYNDPs scenarios. But in cases where the realisation of a new connection is mostly in the interest of the European infrastructure network as a whole, and less needed from the perspective of a national TSO, there is currently no guarantee that the TSO will include this connection into its investment plans, nor a way to force the TSO to do so.

Also, the PCI process aims to stimulate the incorporation of a pan-European perspective on transnational energy infrastructure developments. However, based on the interviews we conducted, we concluded that the PCI status does not seem decisive for TSOs to include certain projects into their investment planning. This status is supportive in terms of PR and the option to attract funding from the CEF, but other considerations are more important for TSOs in their decision making process. This means there is no clear incentive for TSOs to design their projects in order to obtain a PCI status and thus, they are less likely to invest in projects that are necessary from a pan-European viewpoint.

So concluding, with current policies, the planning of transnational energy infrastructure mainly takes place on Member State level. Some processes take place on EU level to incorporate a Pan-European view on the roll-out of interconnections, like the establishment of TYNDP's by the European Network of Transmission System Operators (ENTSOs) and assignment of the Projects of Common Interest (PCIs) by the European Commission. However, the TYNDPs are non-binding and the PCI status can only give a nudge towards incorporation of a Pan-European perspective. All formal competences for the planning and realisation of transnational energy infrastructure are situated at Member State level with national or regional Transmission System Operators, national or local governments and national regulators. This also causes that investments in interconnections are made separately by a large number of TSOs, which means that the decision making process is fragmented.

### 7.1.3 Integrated infrastructure planning

In the last section we concluded that current policies are likely to be insufficient to reach an optimal level of investments in transnational energy infrastructure. To reach this optimal level of investments and incorporate a pan-European view on transnational energy infrastructure planning, integrated infrastructure planning on EU level is necessary. Different options for the policy instrument integrated infrastructure planning are possible.

We identify three different policy options to design the instrument integrated infrastructure planning. The policy options align with policy avenues from Work Package 4.1. The three policy options differ in the level at which the decision-power and responsibilities lie.

1. **Policy option 1 – Fragmented governance.** This policy option most closely resembles the current situation. The policy instrument is based on facilitation of collaboration between Member States, while leaving all responsibilities with the individual Member States and the TSOs operating within their borders. This policy option is most closely aligned with the Green Economic Liberalism Policy Avenue.
2. **Policy option 2 – Pan-European governance.** In this policy option the policy instrument is based on centralisation of governance. All responsibilities for planning, prioritising, deciding, and coordinating transnational infrastructure are transferred to a single European TSO, possibly a new incarnation of the current ENTSOs. This policy option is most closely aligned with the Green Industrial Policy Avenue.
3. **Policy option 3 – Middle-of-the-road.** Policy option 3 lies in between options 1 and 2. Here, the ENTSOs are given the responsibility to set out binding requirements for interconnection between Member States (e.g., X GW between countries A and B by 2040). The ENTSOs requirements are based on pan-European system optimisation. Member States and their TSOs must adhere to these requirements, and bear the responsibility for the planning, governance and operation of the interconnections. This policy option is most closely aligned with the Directed Transition Policy Avenue.

The Policy Avenue Sufficiency and Degrowth focuses on a goal – less consumption – rather than on means and pathways to achieve this goal. Degrowth can indeed be achieved through different roads. Infrastructure governance is therefore orthogonal to the Sufficiency and Degrowth Policy Avenue. Any of the above policy options can be applied to this paradigm.

The following figure shows the governance structure for each of the three policy options.

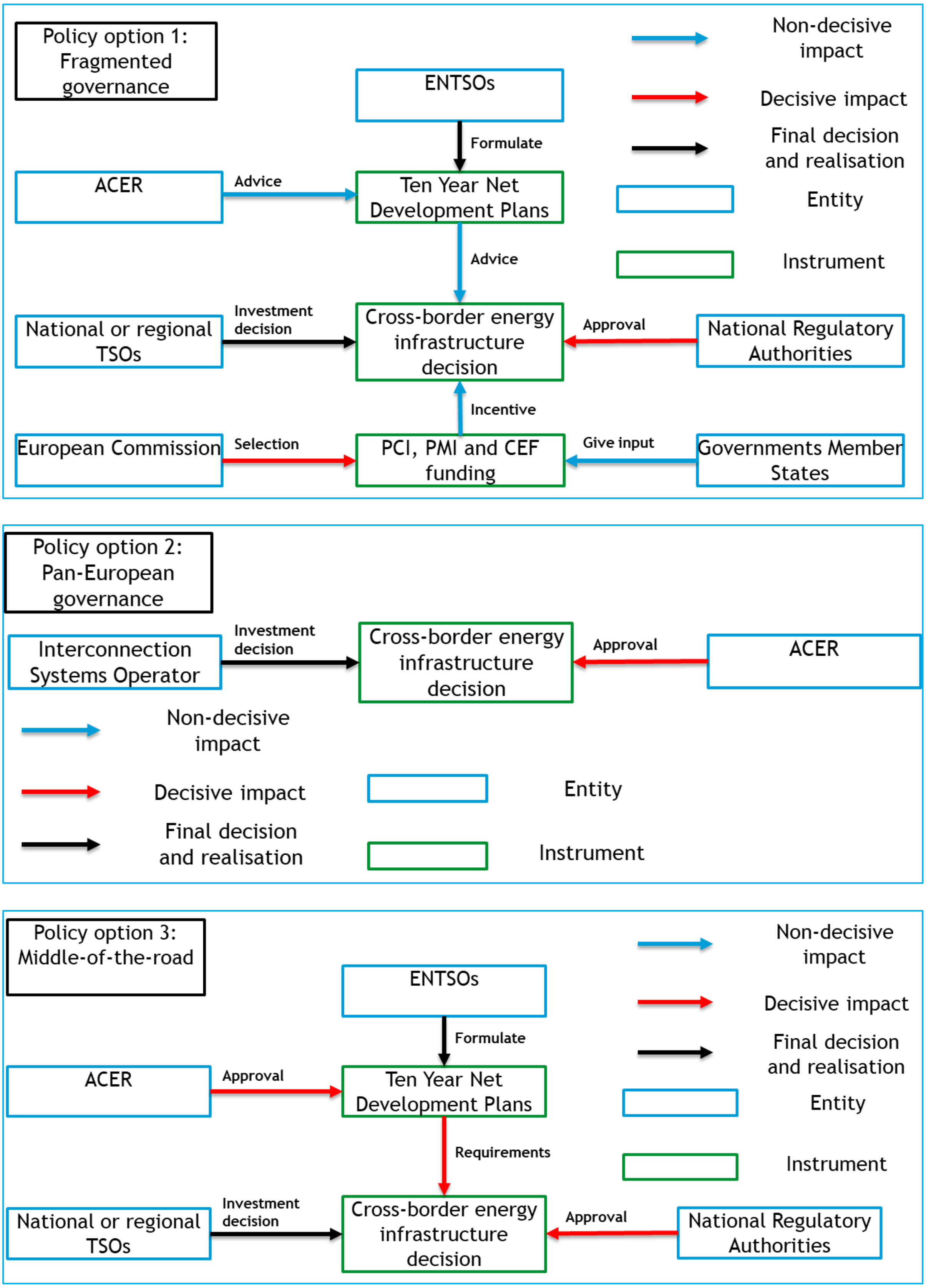



Figure 10. Overview governance structures and policy options

### 7.1.4 Impact assessment policy options

The impact of the three configurations of the policy instrument integrated infrastructure planning on timely and efficient realisation of transnational energy infrastructure was assessed. Table 23 shows the impact assessment of these policy options.

*Table 23 Impact assessment policy options*

| Assessment criteria | Policy option 1: Fragmented governance | Policy option 2: Pan-European governance | Policy option 3: Middle-of-the-road |
|---|---|---|---|
| Ensuring optimal selection of interconnections, from pan-European perspective | No guarantee that pan-European perspective will prevail above national interests. | ISO with complete mandate will guarantee realisation of optimal selection of interconnections. | Binding requirements by ENTSOs for TSOs will guarantee realisation of optimal selection of interconnections. |
| Speed of realisation (once policy option is implemented) | Fragmented planning by large number of TSOs. But faster realisation because of better knowledge local situation. | Integrated planning for whole EU by ISO. But more complex realisation because of limited knowledge local situation. | Two steps in planning process, so more complex. But faster realisation because of better knowledge local situation. |
| Transformative impact | Fragmented planning process and not reasoned from desired end state for EU. | Centralised planning and realisation by ISO, which can reason from desired end state for EU. | Desired end state for EU translates into obligations for Member States, but risk of fragmented planning and realisation. |
| Barriers for implementation | Close to current situation, relatively easy to implement. | Requires significant changes in legislation, which requires political will, implementation time and transfer of knowledge. | Same barriers as policy option 2, but to lesser extent because fewer changes in legislation are necessary. |
| Interaction other policy instruments | For each of the policy options, the interaction with other policy instruments may occur in different manners and on different governance levels. However, in this study we cannot draw conclusion on whether the different policy options interact better or worse with other policy instruments. | | |
| Social and distributional aspects | Realisation by regional or national TSO with less (physical and cultural) distance to the local population. So less risk of negative social and distributional effects. | Risk of poor interaction with local stakeholders, poor balance of costs and benefits and risks of local opposition because of large distance of ISO to local population. Would need to be counteracted explicitly. | Realisation by regional or national TSO with less (physical and cultural) distance to the local population. Accordingly less risk of negative social and distributional effects. |

| **Assessment criteria** | **Policy option 1: Fragmented governance** | **Policy option 2: Pan-European governance** | **Policy option 3: Middle-of-the-road** |
|---|---|---|---|
| Competitiveness and employment | More interconnections lead to lower electricity prices and convergence of prices across EU, which increase competitiveness of EU.<br>No substantial differences for employment. Most of the employment is related to the realisation of the transnational energy infrastructure and it is expected that the realisation of the interconnections will be performed by local contractors in all three policy options. | | |

The main conclusions from this impact assessment are:

- The table shows that each of the three policy option has its benefits and drawbacks. The main distinctive aspects of the policy instruments are their impact on ensuring efficient realisation of transnational energy infrastructure from pan-European perspective, their transformative impact, the barriers for implementation and their impact on risks for negative social and distributional effects. The consideration of the benefits and drawbacks of the policy options is political.
- Policy option 1, which resembles the current situation with governance on member-state level, is not sufficient to guarantee a pan-European view on the realisation of transnational energy infrastructure.
- Policy option 2, with fully centralised European-level governance, is the most transformative. With this policy option, decisions are made on EU-level and one single EU-wide entity has the competences and clout to realise the optimal selection of energy infrastructure.
- However, this policy option is very difficult to implement. This policy option requires a shift of competences from member state level to EU-level. Furthermore, this policy option requires major changes in EU legislation. These aspects make timely realisation of the policy option challenging.
- Furthermore, with policy option 2, the risk of poor interaction with the local stakeholders and consequentially poor balance of costs and benefits and local opposition is much larger because of the large distance to local communities.
- Policy option 3, with an EU entity that gives capacity and timeline requirements for transnational energy infrastructure to member states and national or regional TSOs that realise the interconnections, may be a suitable Middle-of-the-road. With this policy option, it is still possible to realise the optimal selection of interconnections from a pan-European perspective. This policy option is easier to implement and the risks for negative social and distributional effects are smaller.

## 7.2 Policy implications

From the research it can be concluded that a policy instrument which ensures a pan-European view on energy infrastructure planning is necessary for the realisation of an efficient climate neutral European energy system. This pan-European view should be guaranteed within policies and governance, in contrast to the non-binding processes like the TYNPDs of the ENTSOs and the PCI procedures in current legislation. Indeed, to reach the goal of an efficient climate neutral European energy system, a more comprehensive and transformative approach is considered more effective than the current fragmentated decision-making process, which often leads to incremental changes only. The planning of transnational energy infrastructure should be designed from a desired end state of a climate neutral European energy system (back-casting).

Our results show that this comprehensive approach can be implemented most effectively by transferring all competences regarding planning of transnational energy infrastructure to EU level. This implies forming one European Interconnection Systems Operator (ISO) as responsible entity for planning, realisation and operation of transnational energy infrastructure for all energy carriers (option 2).

An EU centralised approach allows for an integral view on the development of not only energy infrastructure, but for the energy system as a whole. Transnational energy infrastructure is just a small part of the total energy system. However, the EU centralised approach could be expanded to other aspects of the energy system, including the development of renewable energy sources, energy storage and energy import, to incorporate a true integral EU view on the development of the entire energy system. This would lead to additional efficiency benefits.

However, realisation of an EU centralised approach is challenging and has drawbacks. Even though transferring all competences for transnational energy infrastructure to the EU level is expected to be the most effective approach for achieving the 2050 objectives, realising this centralised approach is challenging, and severe barriers would need to be overcome. Transferring competences from Member State level to EU level may be opposed by Member States since they will have to give up part of their sovereignty. Furthermore, the increased physical and cultural distance between decision-makers and local communities increases the risk of poor interaction with the local stakeholders, lack of public support, suboptimal spatial planning, delays in permitting processes.

A more middle-of-the-road approach with fewer barriers would be to impose binding requirements to TSOs for the development of transnational energy infrastructure. This is our policy option 3. Here, it would still be possible to implement a pan-European view on the infrastructure and energy system, while keeping competences for the realisation of transnational energy infrastructure at Member State level. However, with this policy option decision-making remains fragmented, which makes it more challenging to effectively incorporate a pan-European view on the development of transnational energy infrastructure and the European energy system as a whole.

Rigorous changes in legislation are expected to be necessary to adequately face the enormous task of reaching climate neutrality in the EU in less than three decades. Even though transferring all competences for transnational energy infrastructure to EU level may seem politically unattainable right now, rigorous and transformative changes like this may be necessary in the transition toward climate neutrality. The policy option with a single pan-European entity that is responsible for all transnational energy infrastructure investments fits well within a policy framework in which all resources within the EU are used to make sure the climate targets are met.

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# Annex 1

Several interviews were conducted during the project. Table 24 gives an overview of the persons and organisations that were interviewed.

*Table 24 Overview interviews*

| Organisation | Name |
|---|---|
| The European Union Agency for the Cooperation of Energy Regulators (ACER) | Jan Kostevc |
| Ministry of Economic Affairs and Climate Policy of the Netherlands | Several employees |
| Gasunie (and involved in ENTSO-G) | Manasseh Struijck |
| | Pieter Boersma |

## About the project

4i-TRACTION – innovation, investment, infrastructure and sector integration:
TRAnsformative policies for a Climate neutral European UnION.

To achieve climate neutrality by 2050, EU policy will have to be reoriented – from incremental towards structural change. As expressed in the European Green Deal, the challenge is to initiate the necessary transformation to climate neutrality in the coming years, while enhancing competitiveness, productivity, employment.

To mobilise the creative, financial and political resources, the EU also needs a governance framework that facilitates cross-sectoral policy integration and that allows citizens, public and private stakeholders to participate in the process and to own the results. The 4i-TRACTION project analyses how this can be done.

## Project partners

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